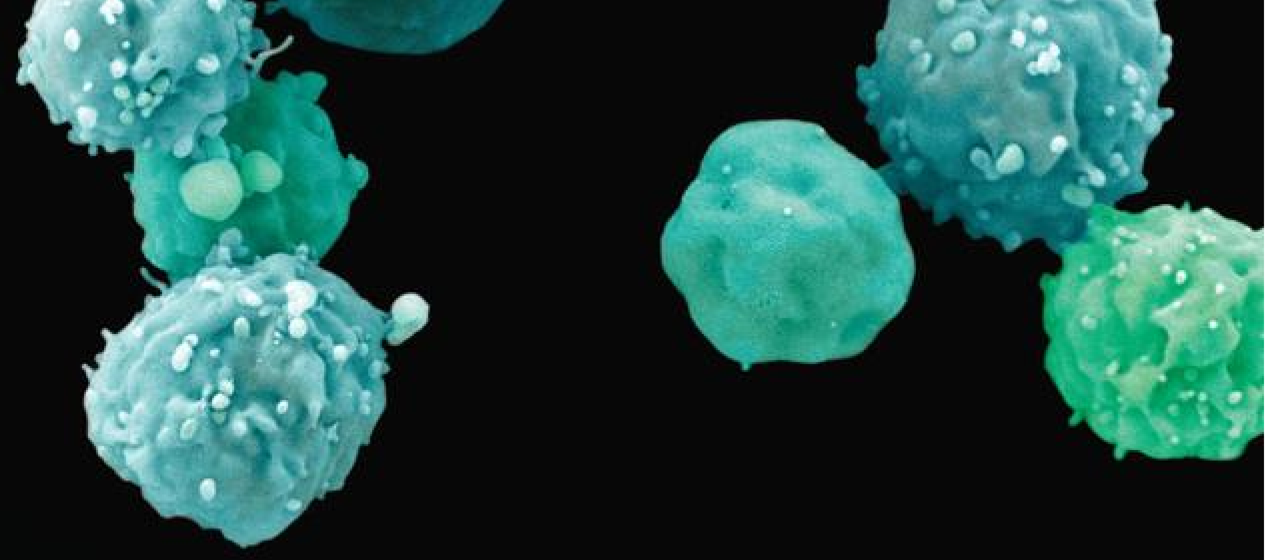
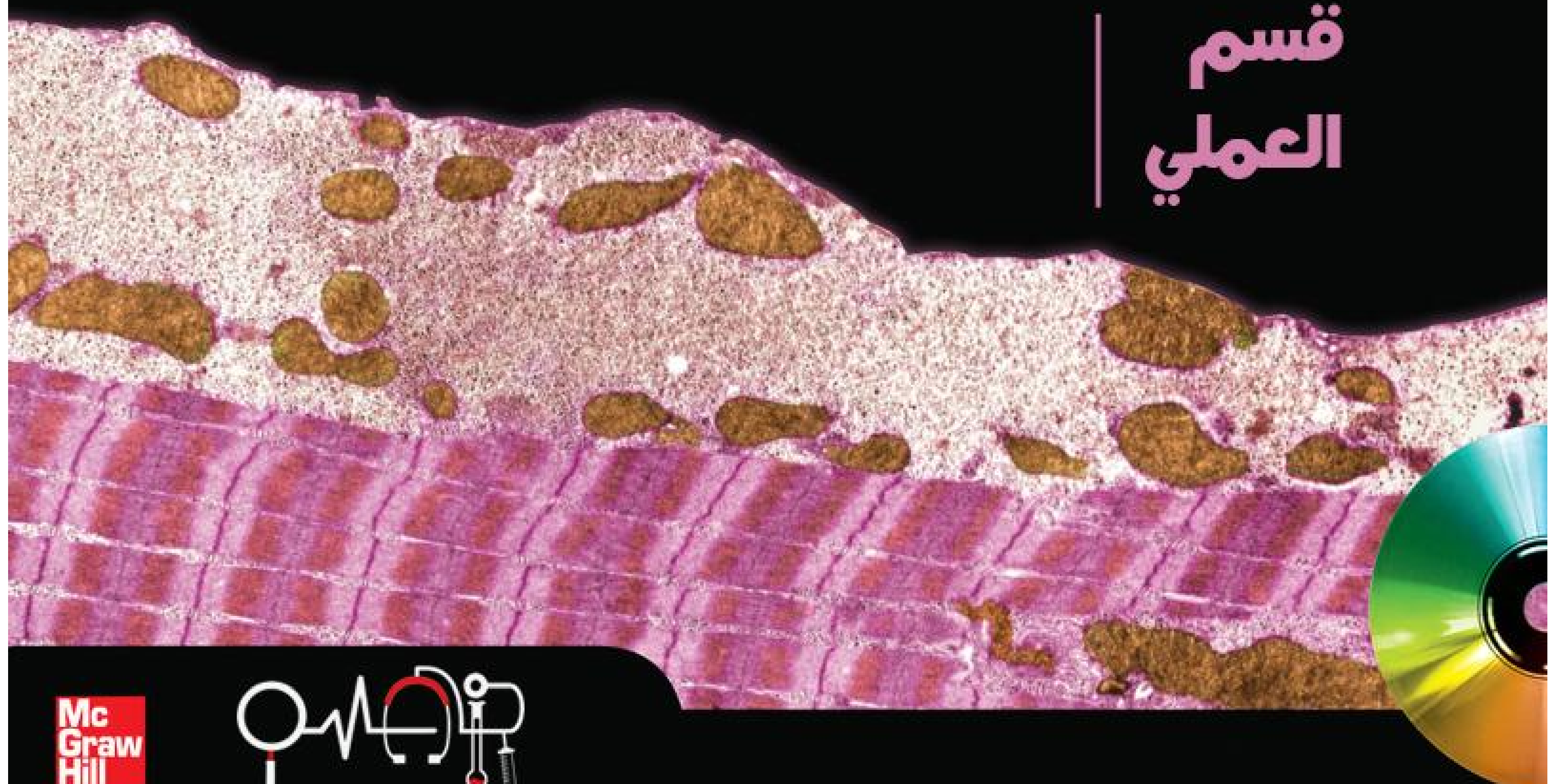


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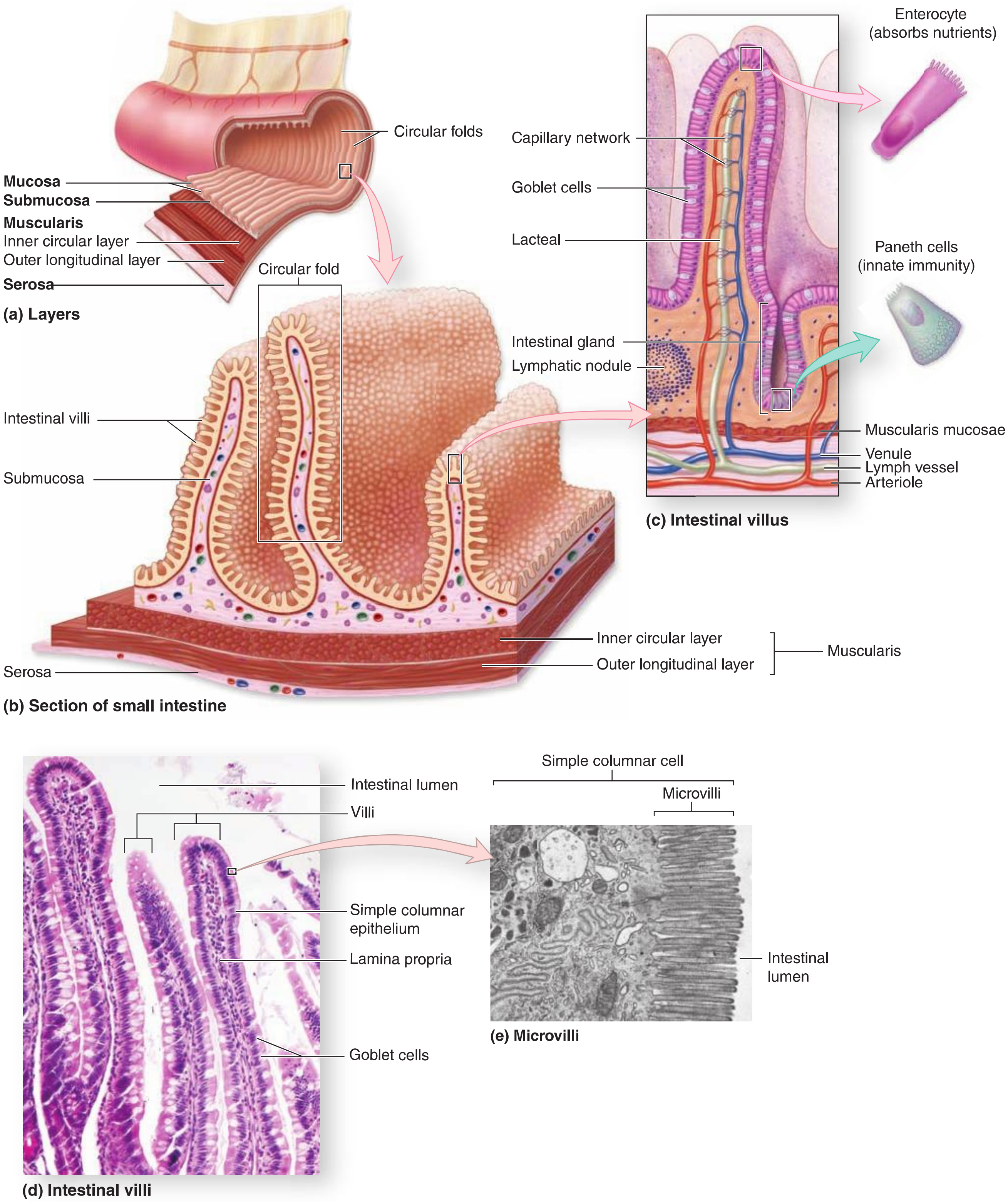
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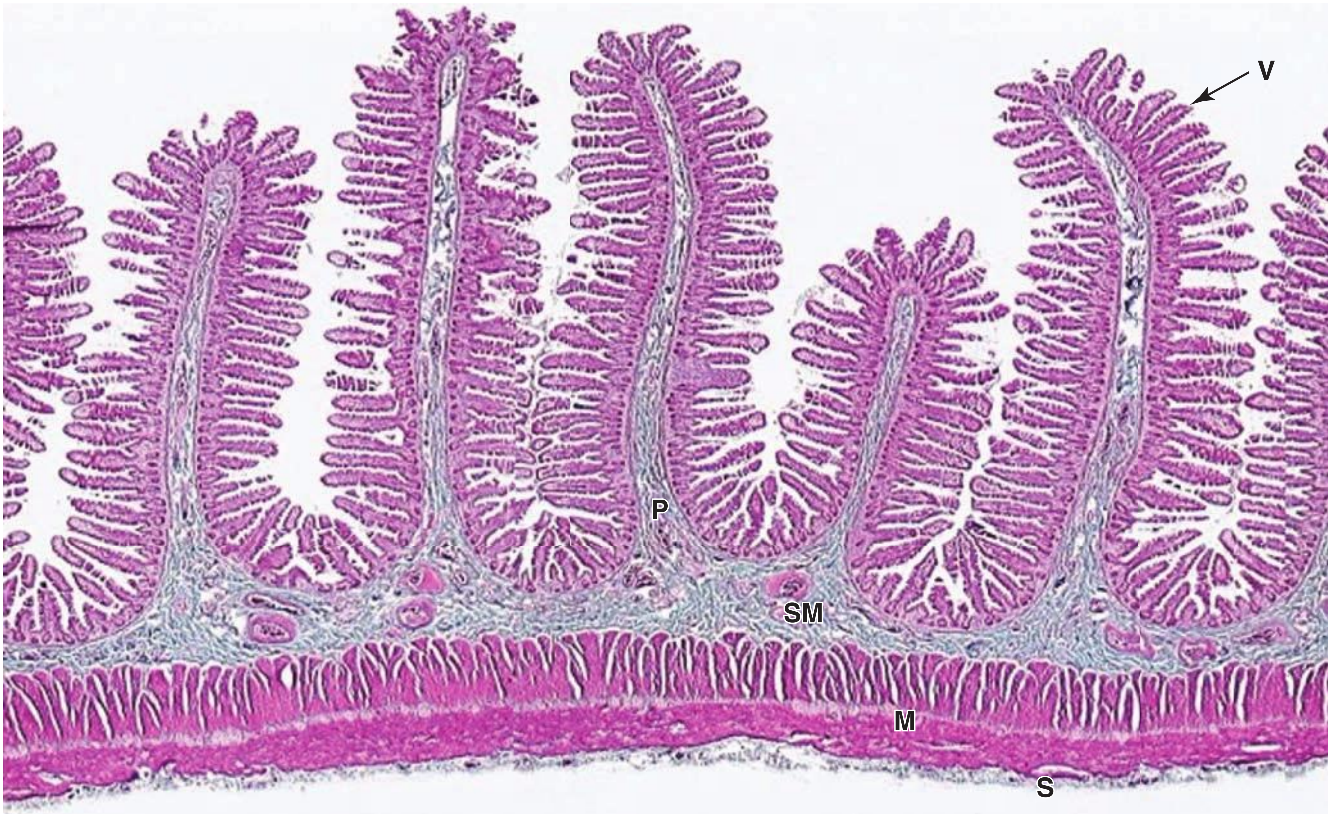
FIGURE **15–22** **Absorptive surface of the small intestine.**



(a) The **mucosa** and **submucosa** are the inner two of the gut's four concentric layers. **(b)** They form circular folds or **plicae circulares**, which increase the absorptive area. **(c)** They are lined by a dense covering of fingerlike projections called **villi**. Internally each villus contains lamina propria connective tissue with microvasculature and lymphatics called **lacteals**.

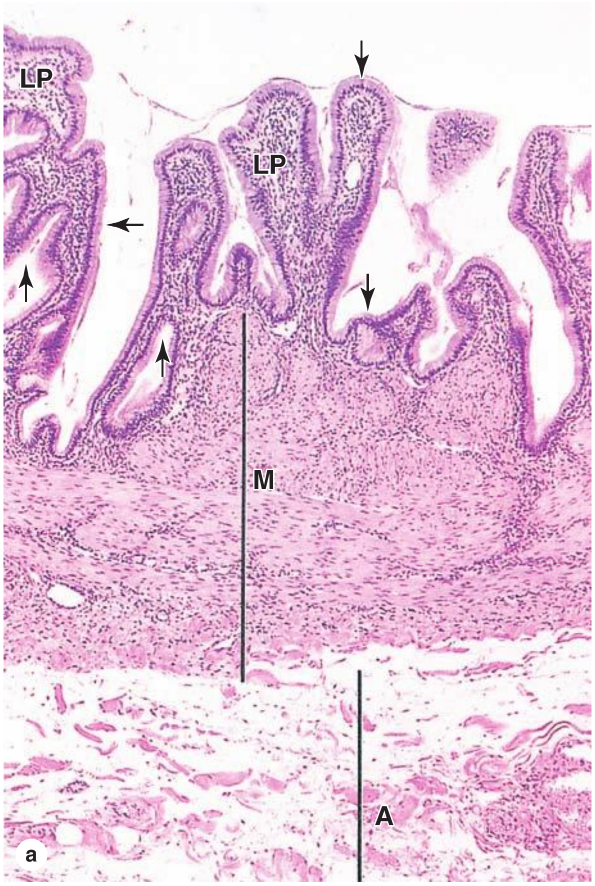
(d) Villi are covered with a simple columnar epithelium composed of absorptive enterocytes and goblet cells. X70. H&E. **(e)** At the apical cell membrane of each enterocyte are located dense **microvilli**, which serve to increase greatly the absorptive surface of the cell. X18,000. TEM.

FIGURE 15–23 Circular folds (plicae circulares) of the jejunum.



The mucosa and submucosa (**SM**) of the small intestine form distinct projecting folds called plicae (**P**), which encircle or spiral around the inner circumference and are best developed in the jejunum. On each fold the mucosa forms a dense covering of projecting structures called **villi** (**V**). In this longitudinal section the two layers of the muscularis (**M**) are clearly distinguished. The inner layer has smooth muscle encircling the submucosa; the outer layer runs lengthwise just inside the serosa (**S**), the gut's outer layer. This arrangement of smooth muscle provides for strong peristaltic movement of the gut's contents. X12. H&E.

FIGURE **16–20** **Gallbladder.**



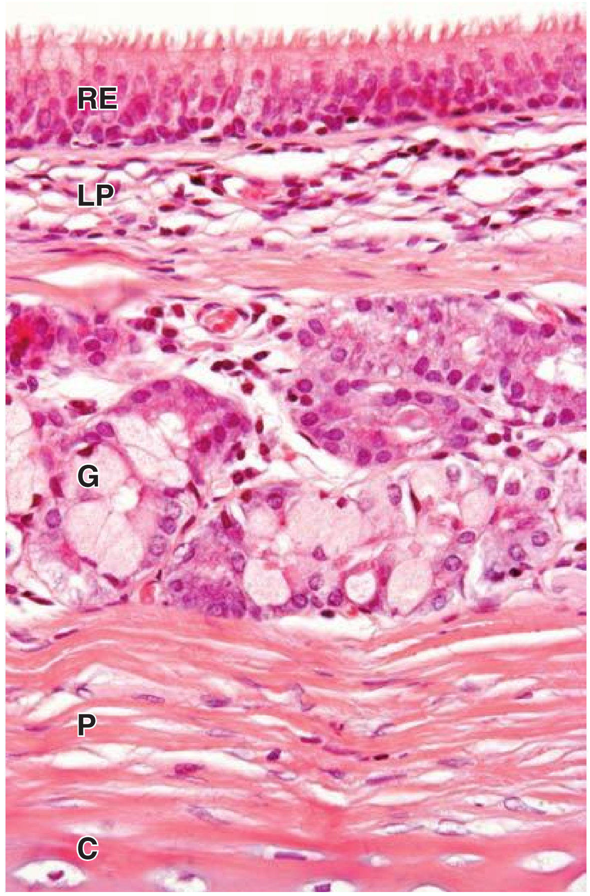


The gallbladder is a saclike structure that stores and concentrates bile, and releases it into the duodenum after a meal. **(a)** Its wall consists largely of a highly folded mucosa, with a simple columnar epithelium (arrows) overlying a typical lamina propria (**LP**); a muscularis (**M**) with bundles of muscle fibers oriented in all directions to facilitate emptying of the organ; and an external adventitia (**A**) where it is against the liver and a serosa where it is exposed. X60. H&E.

(b) TEM of the epithelium shows cells specialized for water uptake across apical microvilli (**MV**) and release into the intercellular spaces (**arrows**) along the folded basolateral cell membranes. From these spaces water is quickly removed by capillaries in the lamina propria. Abundant mitochondria provide the energy for this pumping process. Scattered apical secretory granules (**G**) contain mucus. X5600.

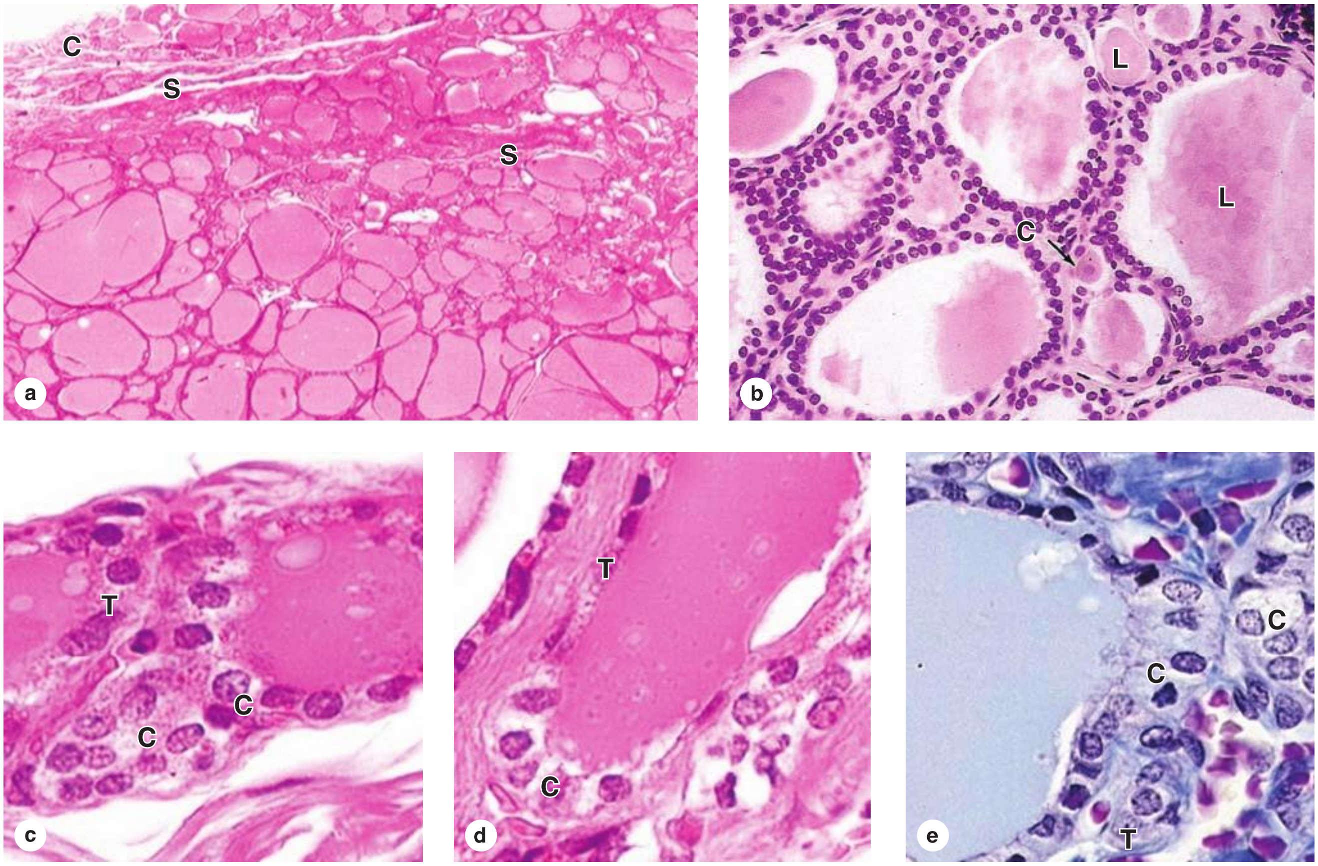
lecture 1

FIGURE **17–5** **Trachea.**



The trachea is lined by typical respiratory epithelium (**RE**) underlain by connective tissue of the lamina propria (**LP**) and seromucous glands (**G**) in the lamina propria and submucosa. The submucosa also contains C-shaped rings of hyaline cartilage (**C**) covered by perichondrium (**P**). X50. H&E.

FIGURE **20–19** **Thyroid follicular cells and parafollicular cells.**

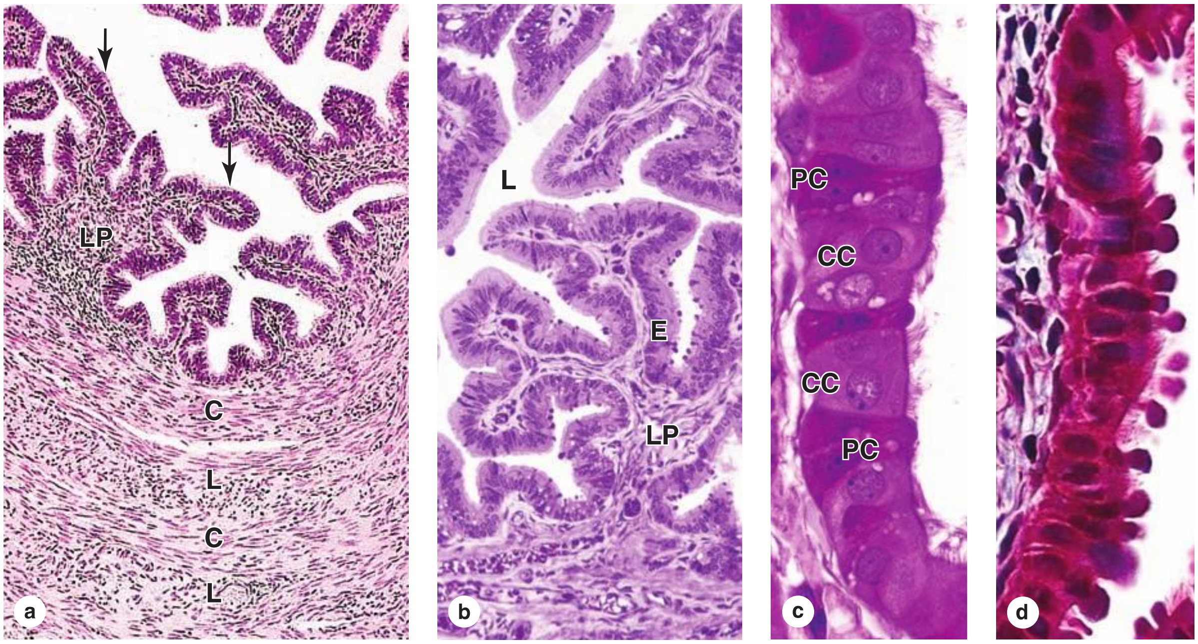


(a) A low-power micrograph of thyroid gland shows the thin capsule (**C**), from which septa (**S**) with the larger blood vessels, lymphatics, and nerves enter the gland. The parenchyma of the organ is distinctive, consisting of colloid-filled epithelial follicles of many sizes. The lumen of each follicle is filled with a lightly staining colloid of a large gelatinous protein called **thyroglobulin**. X12. H&E.

(b) The lumen (**L**) of each follicle is surrounded by a simple epithelium of thyrocytes in which the cell height ranges from squamous to low columnar. Also present are large pale-staining parafollicular or C cells (**C**) that secrete calcitonin, a polypeptide involved with calcium metabolism. X200. H&E.

(**c-e**) C cells may be part of the follicular epithelium or present singly or in groups outside of follicles. Thyrocytes (**T**) can usually be distinguished from parafollicular C cells (**C**) by their smaller size and darker staining properties. Unlike thyrocytes, C cells seldom vary in their size or pale staining characteristics. C cells are somewhat easier to locate in or between small follicles. c and d: X400. H&E; e: X400. Mallory trichrome.

FIGURE **22–15** **Mucosa of the uterine tube wall.**

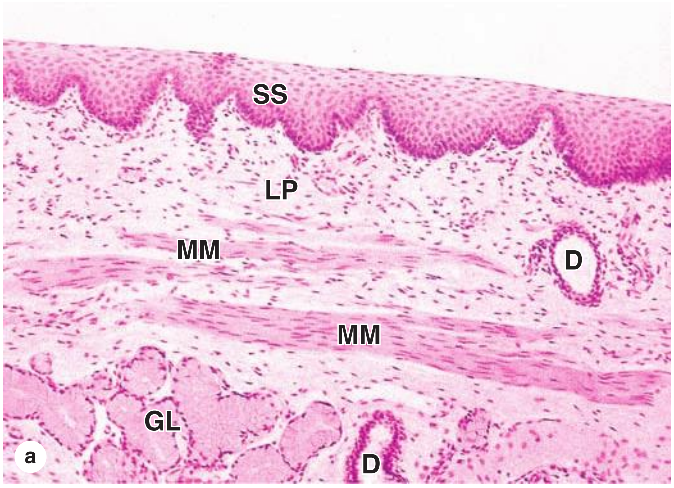


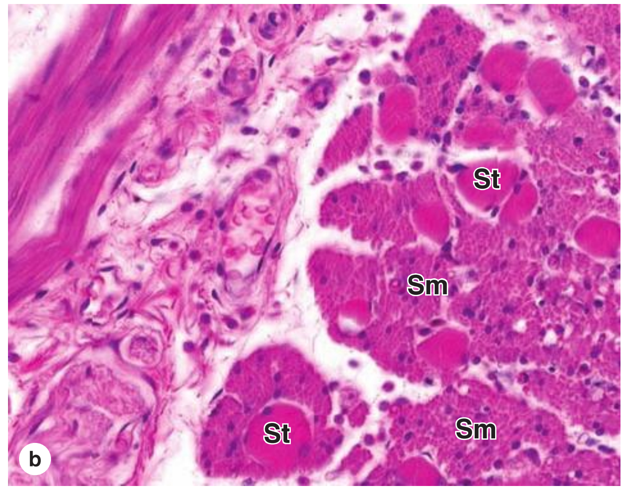
(a) A cross section of the uterine tube at the ampulla shows the interwoven circular (**C**) and longitudinal (**L**) layers of smooth muscle in the muscularis and in the complex of folded mucosa, the lamina propria (**LP**) underlying a simple columnar epithelium (arrows). X140. H&E.

(b) The oviduct mucosa, with folds projecting into the lumen (**L**), has simple columnar epithelium (**E**) on the lamina propria (**LP**). X200. PT.

(**c, d**) Higher magnification of the epithelium shows two cell types: ciliated cells (**CC**) interspersed with the secretory peg cells (**PC**), which produce the nutritive fluid covering the epithelium. These cells' histologic and functional features vary during the ovarian cycle due to hormonal fluctuations. In **(d)** the peg cells shown are at their most developed and most active state in the period shortly after ovulation when an embryo might be present. c: X400, PT; d: X400, Mallory trichrome.

FIGURE **15–13** **Esophagus.**



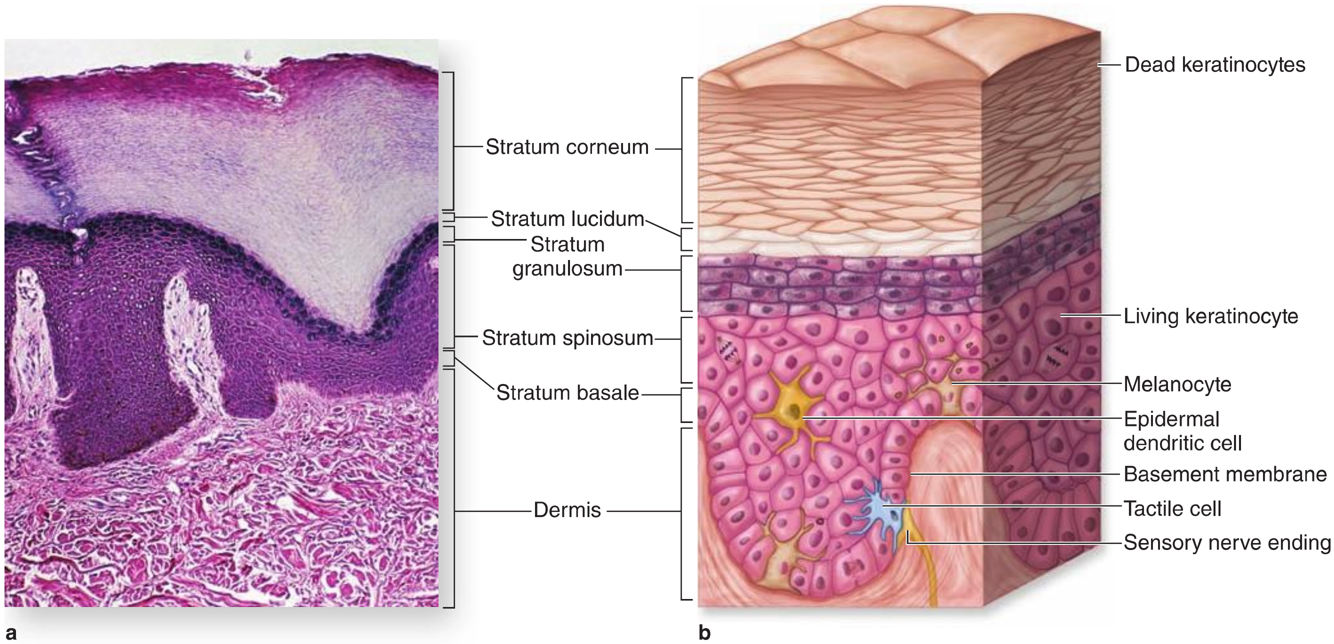


(a) Longitudinal section of esophagus shows mucosa consisting of nonkeratinized stratified squamous epithelium (**SS**), lamina propria (**LP**), and smooth muscles of the muscularis mucosae (**MM**). Beneath the mucosa is the submucosa containing esophageal mucous glands (**GL**) that empty via ducts (**D**) onto the luminal surface. X40. H&E.

(b) Transverse section showing the muscularis halfway along the esophagus reveals a combination of large skeletal or striated muscle fibers (**St**) and smooth muscle fibers (**Sm**) in the outer layer, which is cut transversely here. This transition from muscles under voluntary control to the type controlled autonomically is important in the swallowing mechanism. X200. H&E.

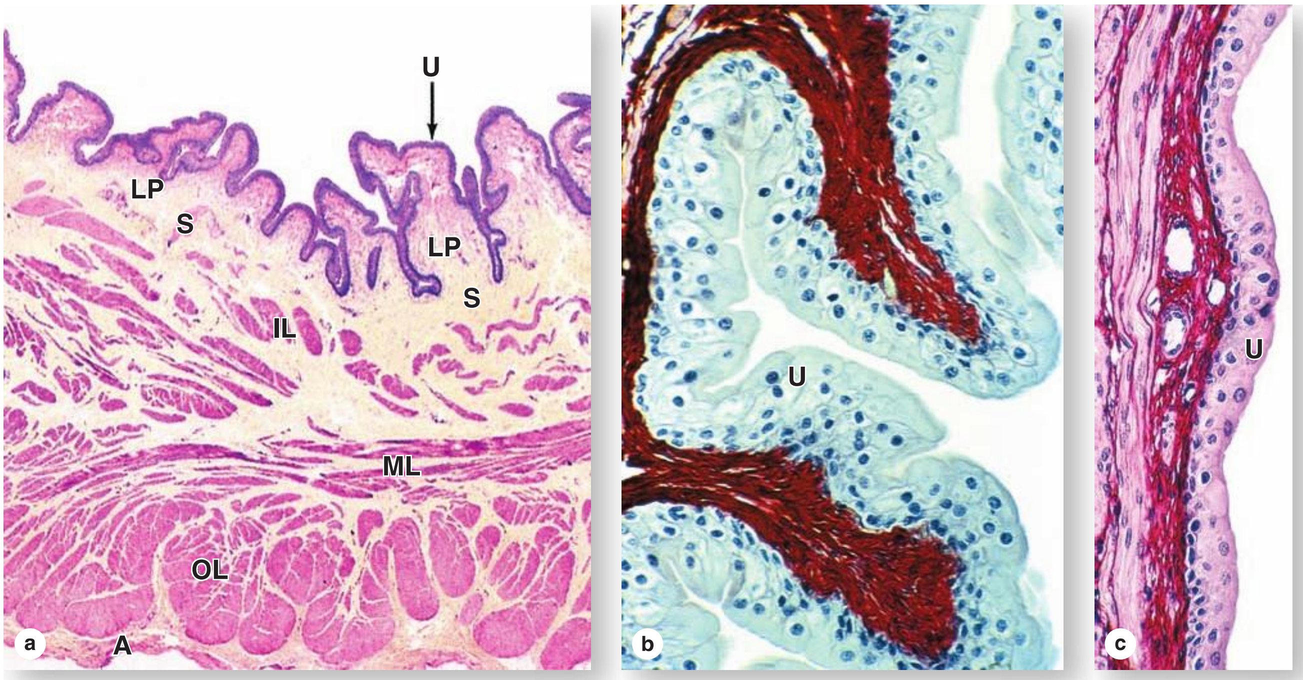
lecture 2

FIGURE **18–2** **Layers (strata) of epidermis in thick skin.**



(a) Micrograph shows the sequence of the epidermal layers in thick skin and the approximate sizes and shape of keratinocytes in these layers. Also shown are the coarse bundles of collagen in the dermis and on the far left, the duct from a sweat gland entering the epidermis from a dermal papilla and coiling to a surface pore through all the strata. X100. H&E. **(b)** Diagram illustrating the sequence of the epidermal layers also indicates the normal locations of three important nonkeratinocyte cells in the epidermis: melanocytes, a Langerhans cell, and a tactile Merkel cell.

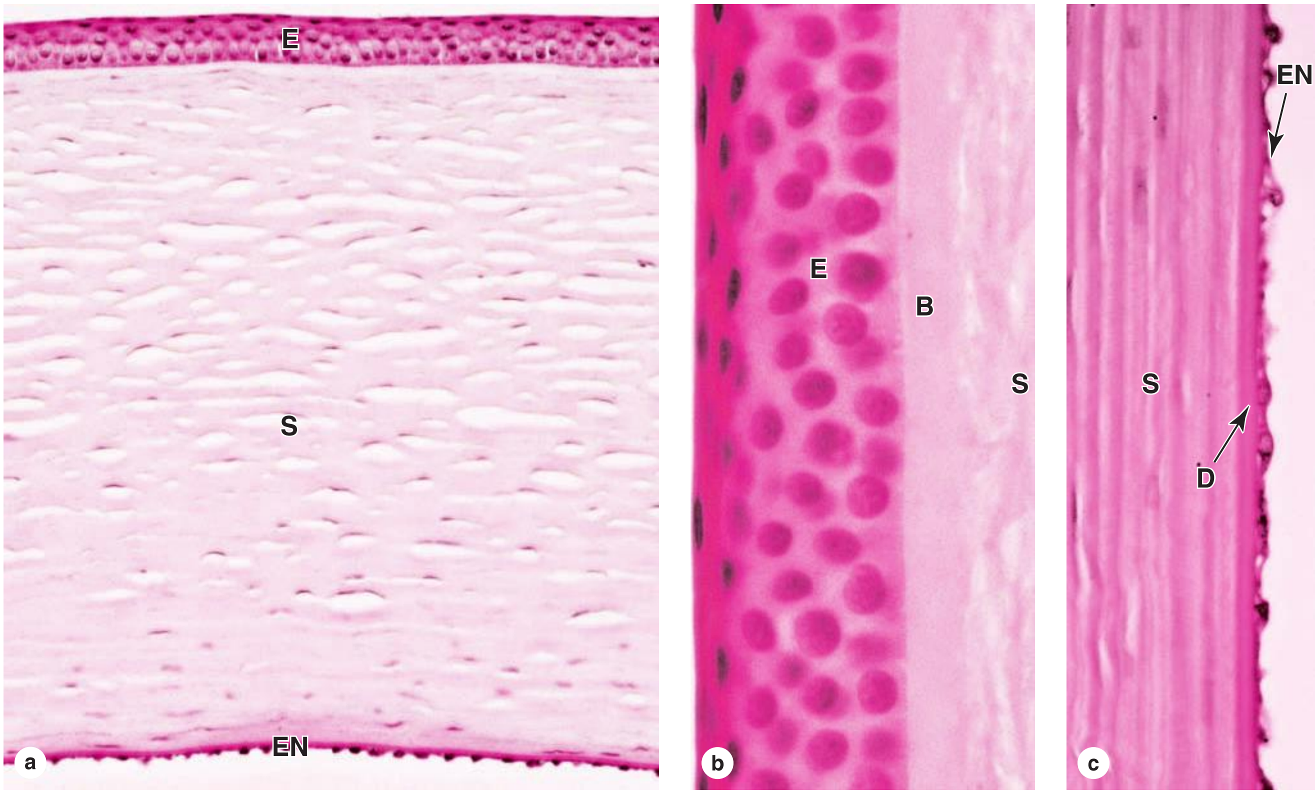
FIGURE **19–17** **Bladder wall and urothelium.**



(a) In the neck of the bladder, near the urethra, the wall shows four layers: the mucosa with urothelium (**U**) and lamina propria (**LP**); the thin submucosa (**S**); inner, middle, and outer layers of smooth muscle (**IL**, **ML**, and **OL**); and the adventitia (**A**). X15. H&E.

(b) When the bladder is empty, the mucosa is highly folded and the urothelium (**U**) has bulbous umbrella cells. X250. PSH. **(c)** When the bladder is full, the mucosa is pulled smooth, the urothelium (**U**) is thinner, and the umbrella cells are flatter. X250. H&E.

FIGURE **23–3** **Cornea.**

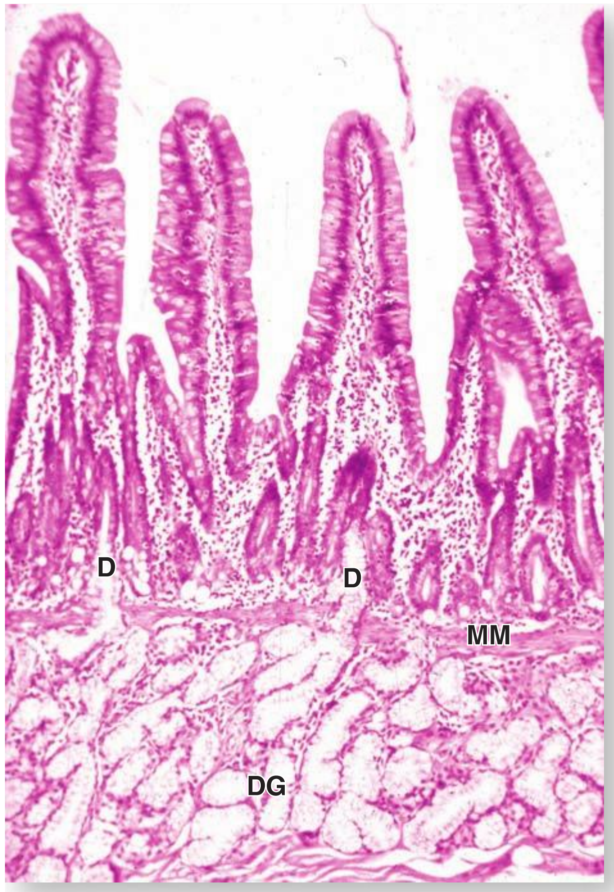


The anterior structure of the eye, the cornea has five layers. **(a)** The external stratified squamous epithelium (**E**) is nonkeratinized, five or six cells thick, and densely supplied with sensory-free nerve endings that trigger the blinking reflex. The stroma (**S**) comprises approximately 90% of the cornea's thickness, consisting of some 60 layers of long type I collagen fibers arranged in a precise orthogonal array and alternating with flattened cells called **keratocytes**. The stroma is lined internally by endothelium (**EN**). X100. H&E.

(b) The corneal epithelium (**E**) rests firmly on the thick homogeneous Bowman's membrane (**B**). The stroma (**S**) is completely avascular, and nutrients reach the keratocytes and epithelial cells by diffusion from the surrounding limbus and aqueous humor behind the cornea. X400. H&E. **(c)** The posterior surface of the cornea is covered by simple squamous epithelium (**EN**) that rests on another thick, strong layer called Descemet's membrane (**D**) adjacent to the stroma (**S**). X400. H&E.

lecture 3

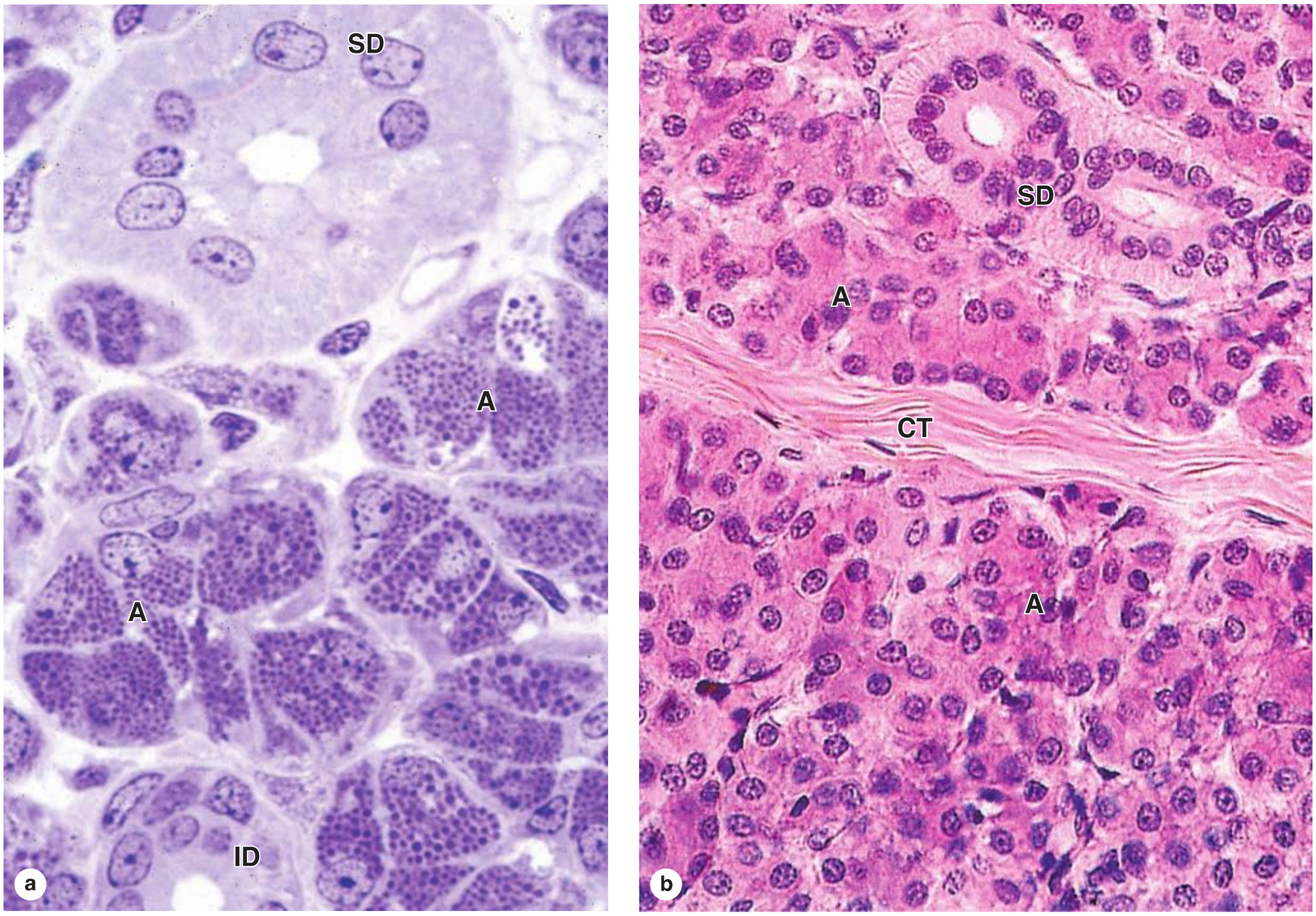
FIGURE **15–29** **Duodenal (Brunner) glands.**



Concentrated in the upper duodenum are large masses of compound branched **mucous glands**, the duodenal glands (**DG**), with many lobules that occupy much of the submucosa and may extend above the muscularis mucosae (**MM**) into the mucosa. Many small excretory ducts (**D**) extend from these lobules through the lamina propria and empty into the lumen among the small intestinal crypts. Alkaline mucus from duodenal glands neutralizes the pH of material entering the duodenum and supplements the mucus from goblet cells in lubricating and protecting the lining of the small intestine. X100. H&E.

lecture 3

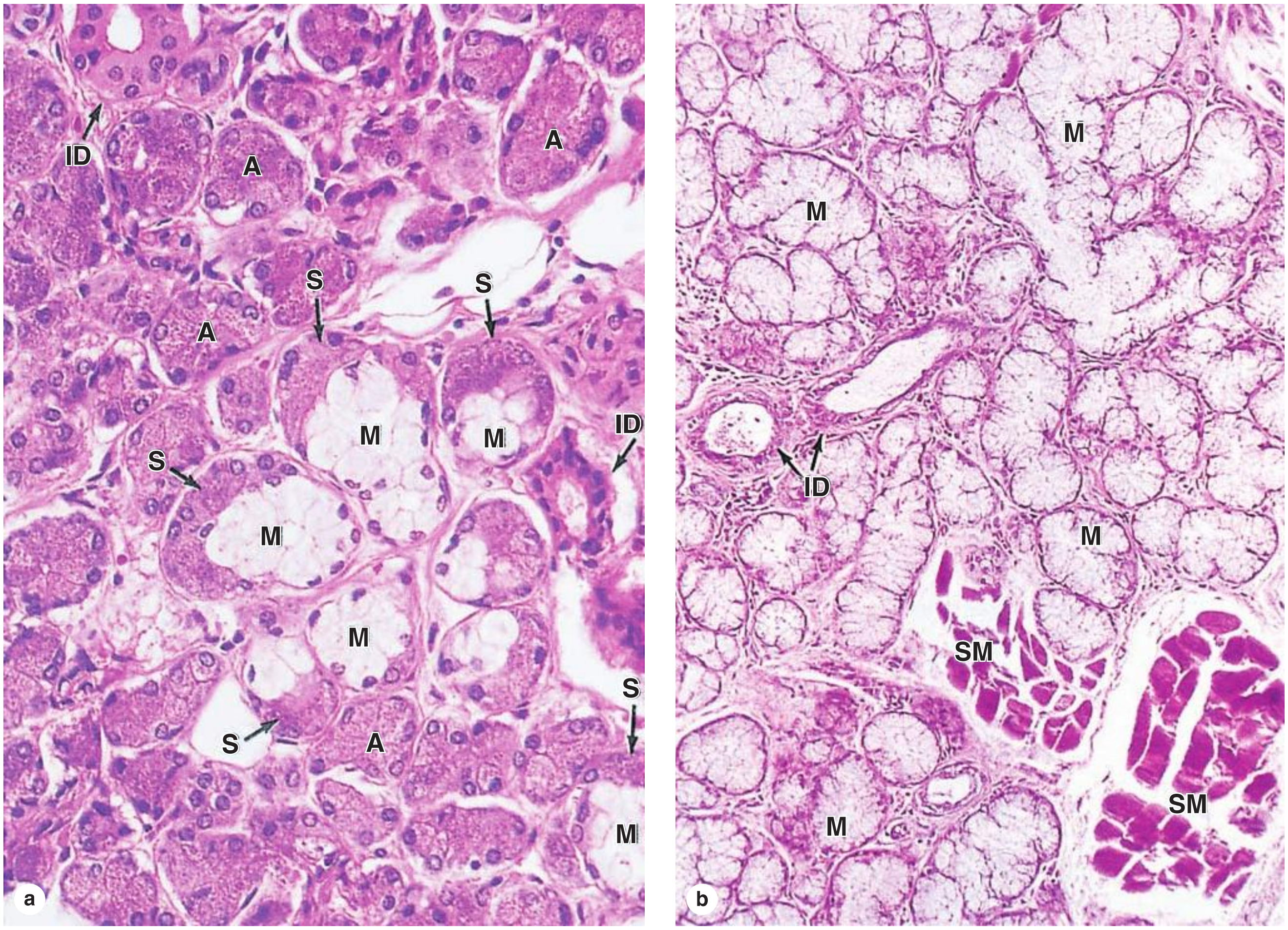
FIGURE **16–3** **Parotid gland.**



The large parotid gland consists entirely of serous acini with cells producing amylase and other proteins for storage in secretory granules. **(a)** Micrograph of a parotid gland shows densely packed serous acini (**A**) with ducts. Secretory granules of serous cells are clearly shown in this plastic section, as well as an intercalated duct (**ID**) and striated duct (**SD**), both cut transversely. X400. PT.

(b) Striations of a duct (**SD**) are better seen here, along with a septum (**CT**) and numerous serous acini (**A**). The connective tissue often includes adipocytes. X200. H&E.

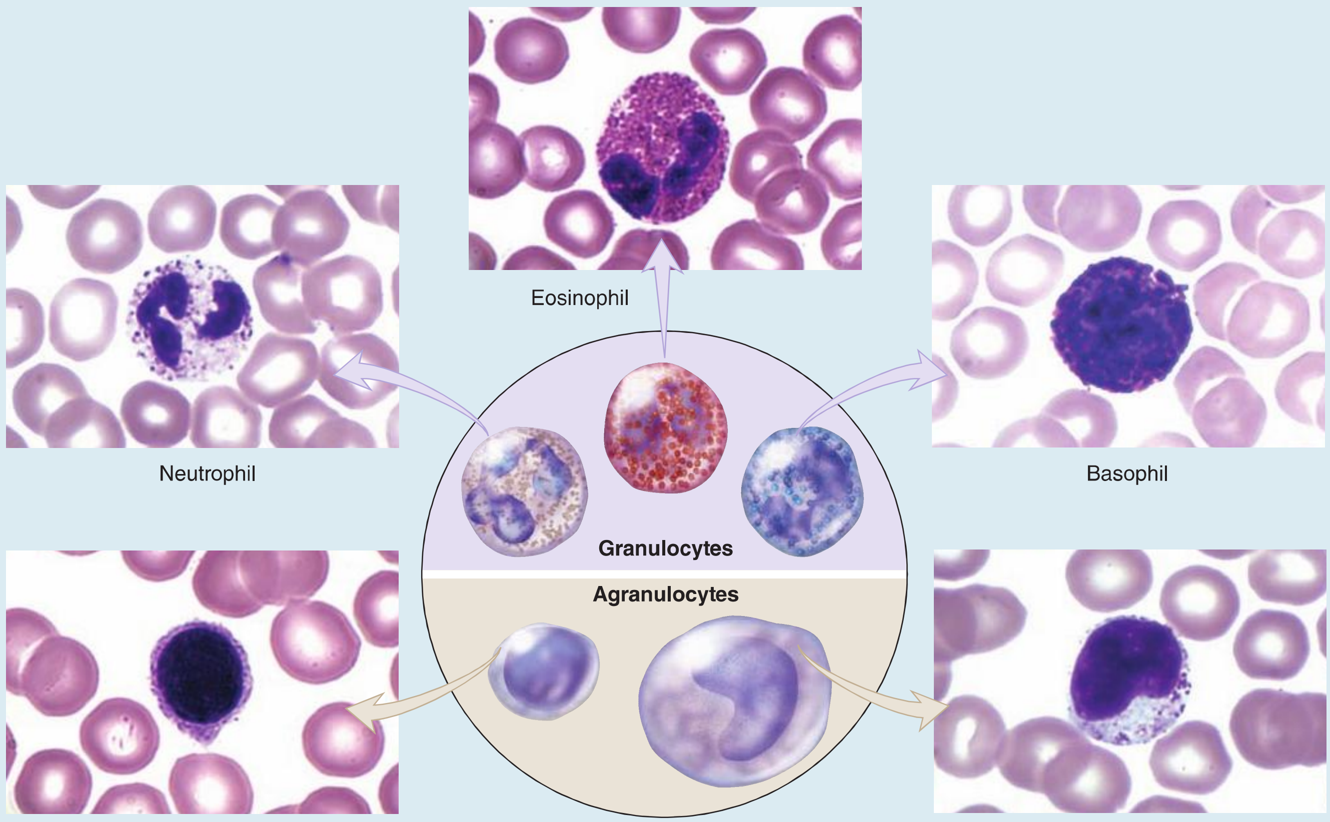
FIGURE 16–5 **Submandibular gland and sublingual gland.**



(a) The submandibular gland is a mixed serous and mucous gland (serous cells predominate), and shows well-stained serous acini (**A**) and serous demilunes (**S**) and pale-staining mucous cells (**M**) grouped as tubules in this tubuloacinar gland. Small intralobular ducts (**ID**) drain each lobule. X340. H&E.

(b) The sublingual gland is a mixed but largely mucous gland with a tubuloacinar arrangement of poorly stained mucous cells (**M**). Small intralobular ducts (**ID**) are seen in connective tissue, as well as small fascicles of lingual striated muscle (**SM**). X140. H&E.

TABLE 12–2 Leukocytes: Numbers, structural features, and major functions.



Type	Nucleus	Specific Granules[a]	Differential Count[b] (%)	Life Span	Major Functions
Granulocytes					
Neutrophils	3-5 lobes	Faint/light pink	57-67	1-4 d	Kill and phagocytose bacteria
Eosinophils	Bilobed	Red/dark pink	1-3	1-2 wk	Kill helminthic and other parasites; modulate local inflammation
Basophils	Bilobed or S-shaped	Dark blue/purple	0-0.75	Several months	Modulate inflammation, release histamine during allergy
Agranulocytes					
Lymphocytes	Rather spherical	(none)	25-33	Hours to many years	Effector and regulatory cells for adaptive immunity
Monocytes	Indented or C-shaped	(none)	3-7	Hours to years	Precursors of macrophages and other mononuclear phagocytic cells

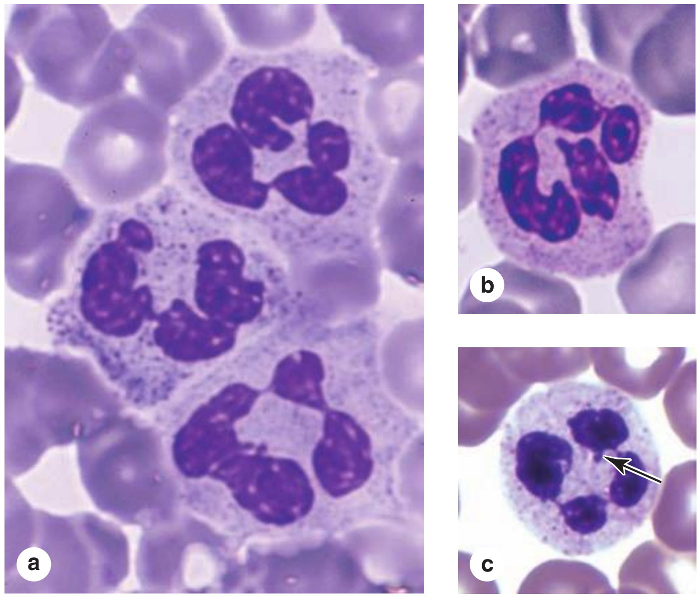
[a]Color with routine blood smear stains. There are typically 4500-11,000 total leukocytes/μL of blood in adults, higher in infants and young children.

[b]The percentage ranges given for each type of leukocyte are those used by the U.S. National Board of Medical Examiners. The value for neutrophils includes 3%-5% circulating, immature band forms.

All micrographs X1600.

lecture 4

FIGURE 12–7 **Neutrophils.**

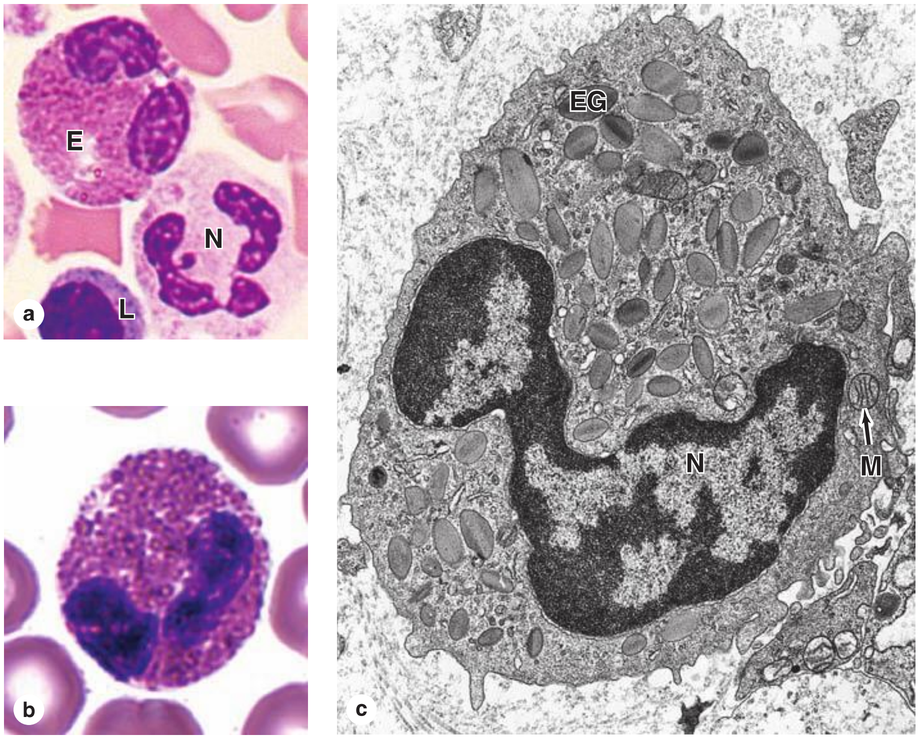


(a) In blood smears neutrophils can be identified by their multilobulated nuclei, with lobules held together by very thin strands. With this feature, the cells are often called **polymorphonuclear leukocytes**, PMNs, or just **polymorphs**. The cells are dynamic and the nuclear shape changes frequently. X1500. Giemsa.

(b) Neutrophils typically have diameters ranging from 12 to 15 μm, approximately twice that of the surrounding erythrocytes. The cytoplasmic granules are relatively sparse and have heterogeneous staining properties, although generally pale and not obscuring the nucleus. X1500. Giemsa.

(c) Micrograph showing a neutrophil from a female in which the condensed X chromosome appears as a drumstick appendage to a nuclear lobe (arrow). X1500. Wright.

FIGURE **12–9** **Eosinophils.**

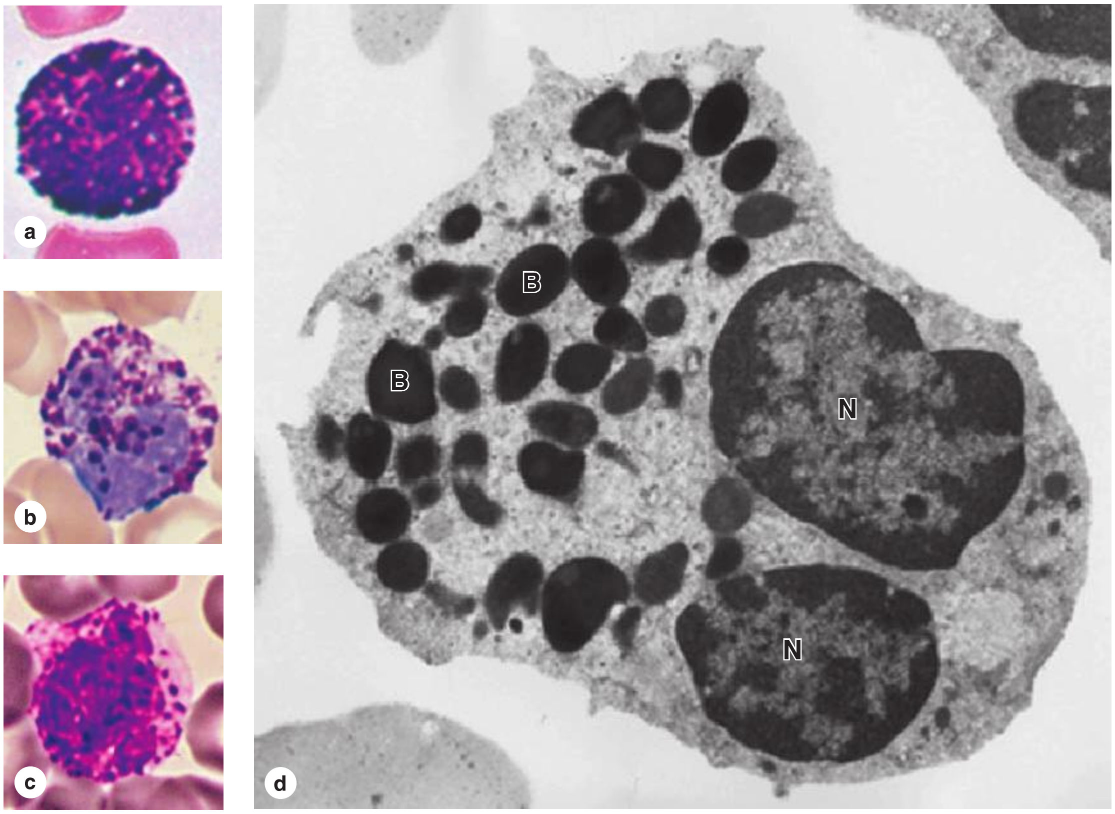


Eosinophils are about the same size as neutrophils but have bilobed nuclei and more abundant coarse cytoplasmic granules. The cytoplasm is often filled with brightly eosinophilic specific granules, but it also includes some azurophilic granules. **(a)** Micrograph shows an eosinophil (**E**) next to a neutrophil (**N**) and a small lymphocyte (**L**). X1500. Wright.

(b) Even with granules filling the cytoplasm, the two nuclear lobes of eosinophils are usually clear. X1500. Giemsa.

(c) Ultrastructurally a sectioned eosinophil clearly shows the unique specific eosinophilic granules (**EG**), as oval structures with disc-shaped electron-dense, crystalline cores. These granules, along with a few lysosomes and mitochondria (**M**), fill the cytoplasm around the bilobed nucleus (**N**). X20,000.

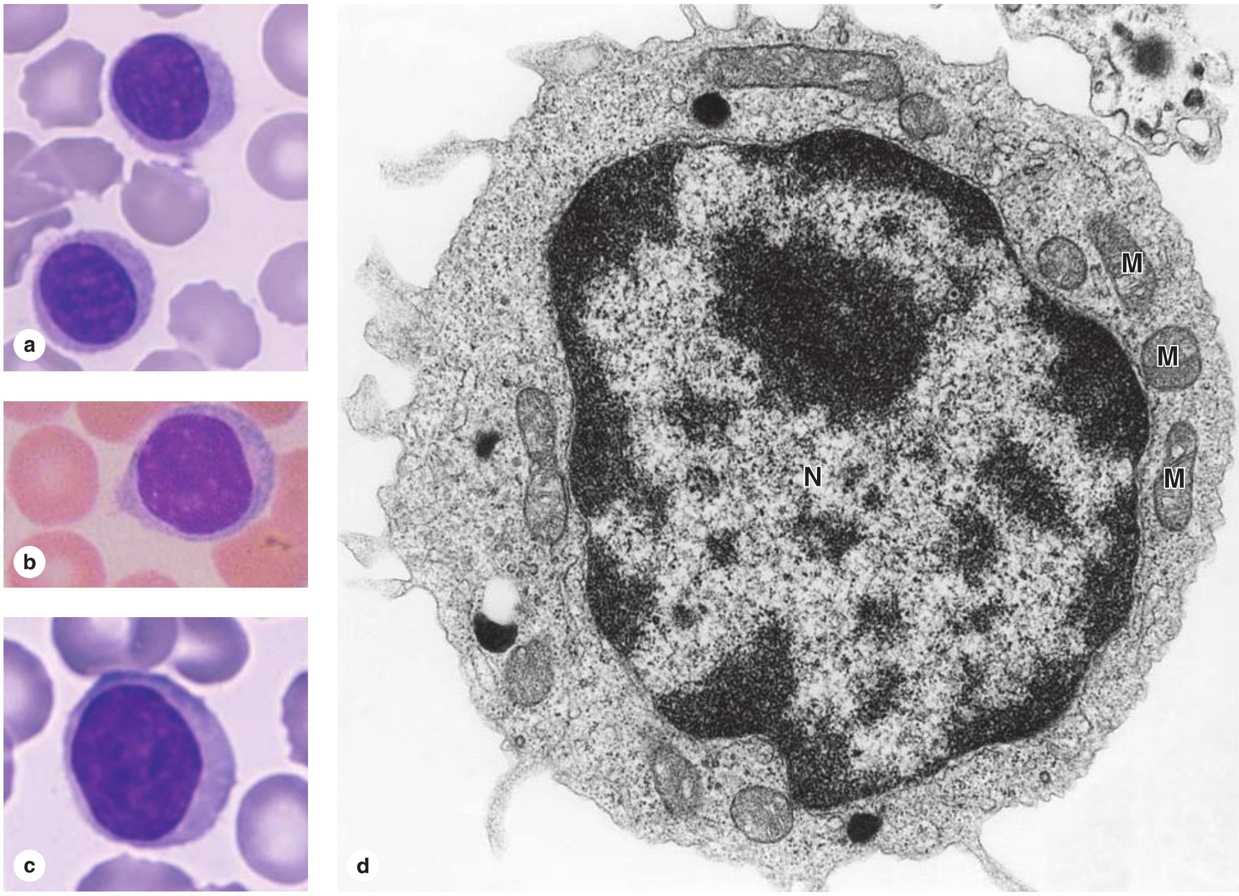
FIGURE **12–10** **Basophils.**



(a-c) Basophils are also approximately the same size as neutrophils and eosinophils, but they have large, strongly basophilic specific granules that usually obstruct the appearance of the nucleus which usually has two large irregular lobes. a and b: X1500, Wright; c: X1500, Giemsa.

(d) A TEM of a sectioned basophil reveals the single bilobed nucleus (**N**) and the large, electron-dense specific basophilic granules (**B**). Basophils exert many activities modulating the immune response and inflammation and have many functional similarities with mast cells, which are normal, longer-term residents of connective tissue. X25,000.

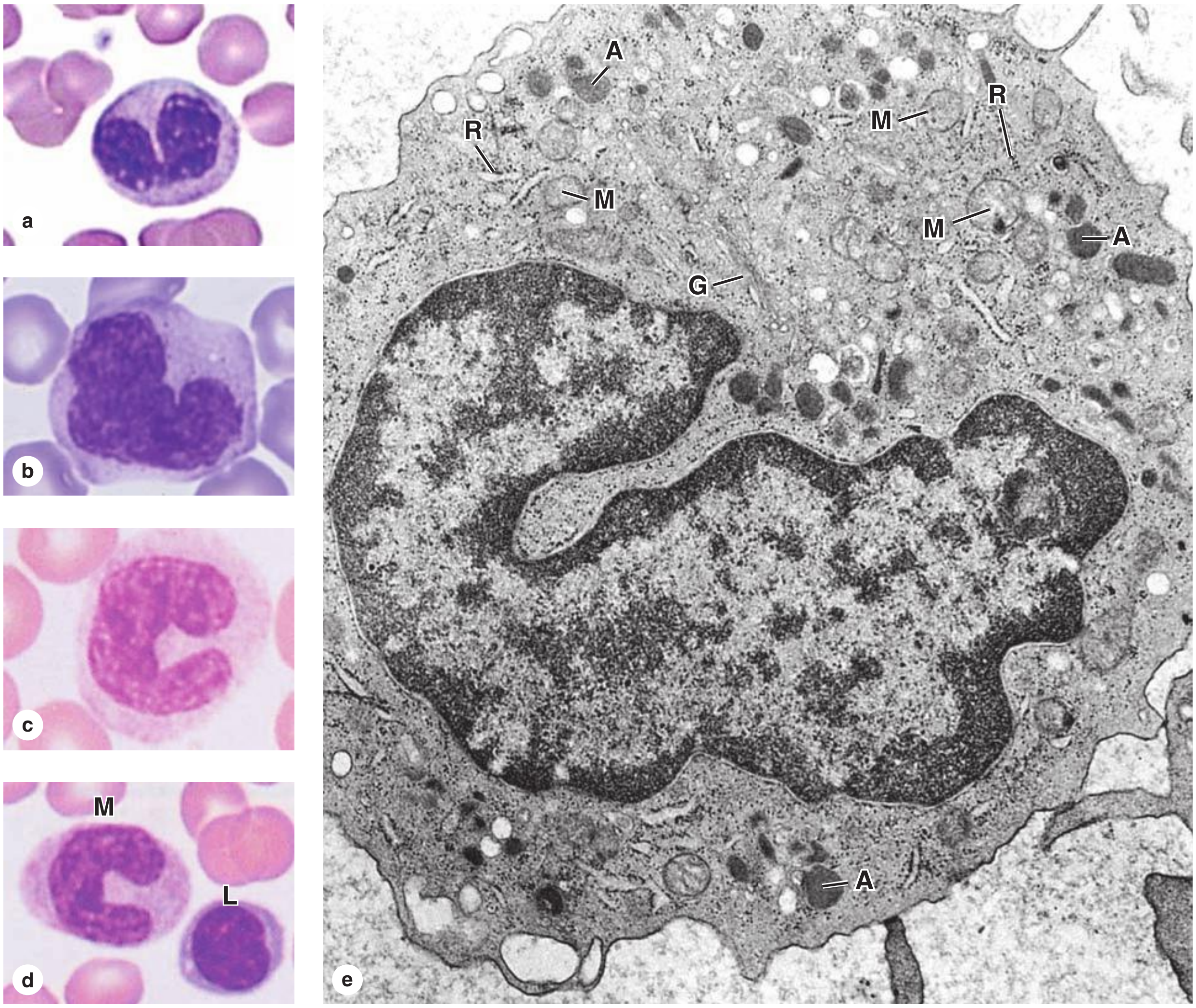
FIGURE **12–11** **Lymphocytes.**



Lymphocytes are agranulocytes and lack the specific granules characteristic of granulocytes. Lymphocytes circulating in blood generally range in size from 6 to 15 μm in diameter and are sometimes classified arbitrarily as small, medium, and large. **(a)** The most numerous small lymphocytes shown here are slightly larger than the neighboring erythrocytes and have only a thin rim of cytoplasm surrounding the spherical nucleus. X1500. Giemsa. **(b)** Medium lymphocytes are distinctly larger than erythrocytes. X1500. Wright. **(c)** Large lymphocytes, much larger than erythrocytes, may represent activated cells that have returned to the circulation. X1500. Giemsa. **(d)** Ultrastructurally a medium-sized lymphocytes is seen to be mostly filled with a euchromatic nucleus (**N**) surrounded by cytoplasm containing mitochondria (**M**), free polysomes, and a few dark lysosomes (azurophilic granules). X22,000.

lecture 4

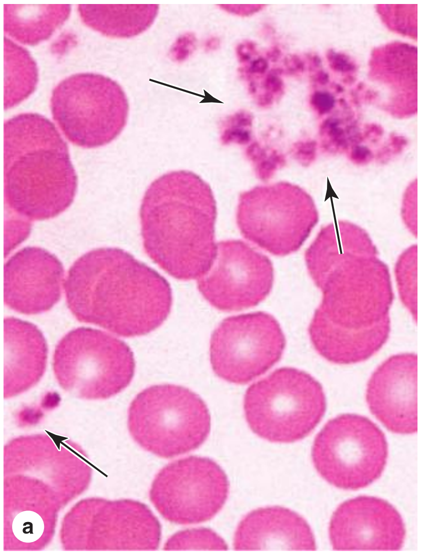
FIGURE **12–12** **Monocytes.**

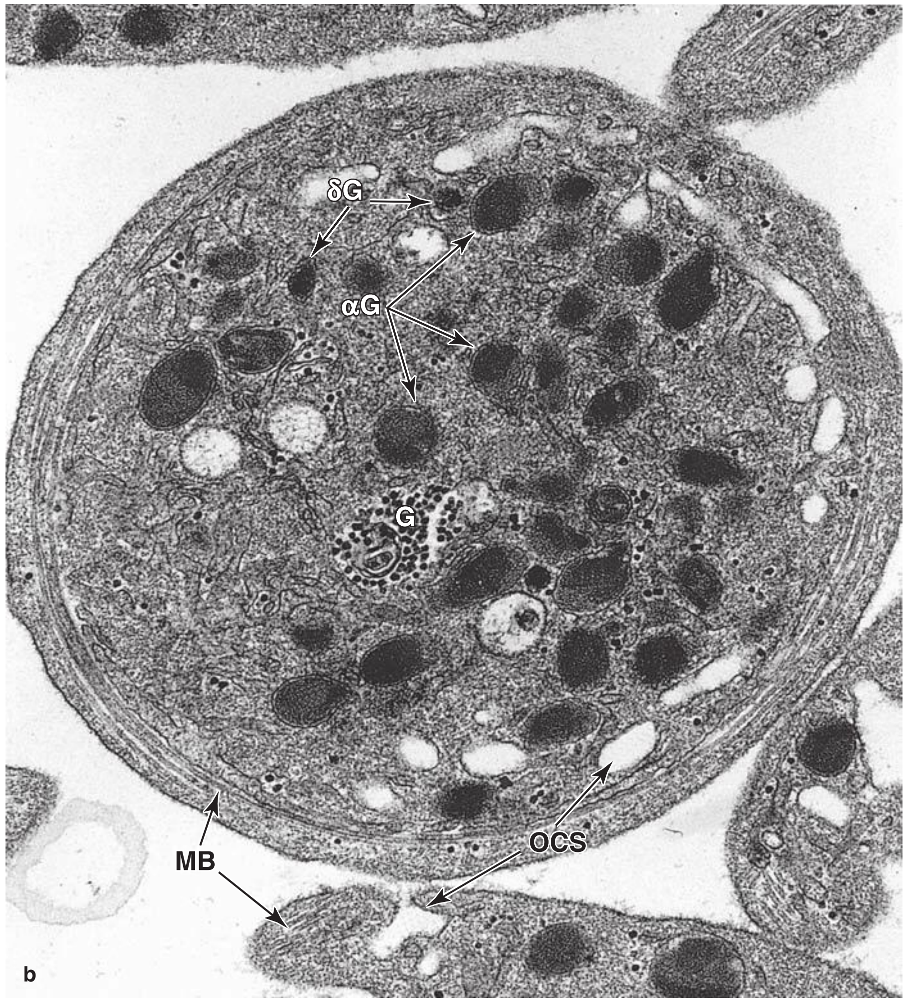


Monocytes are large agranulocytes with diameters from 12 to 20 μm that circulate as precursors to macrophages and other cells of the mononuclear phagocyte system.
(a-d) Micrographs of monocytes showing their distinctive nuclei which are indented, kidney-shaped, or C-shaped. a: X1500, Giemsa; b-d: X1500, Wright. **(e)** Ultrastructurally the cytoplasm of a monocyte shows a Golgi apparatus (**G**), mitochondria (**M**), and lysosomes or azurophilic granules (**A**). Rough ER is poorly developed and there are some free polysomes (**R**). X22,000.

(*Figure 12-12e, with permission, from D.F. Bainton and M.G. Farquhar, Department of Pathology, University of California at San Francisco, CA.*)

FIGURE 12–13 Platelets.





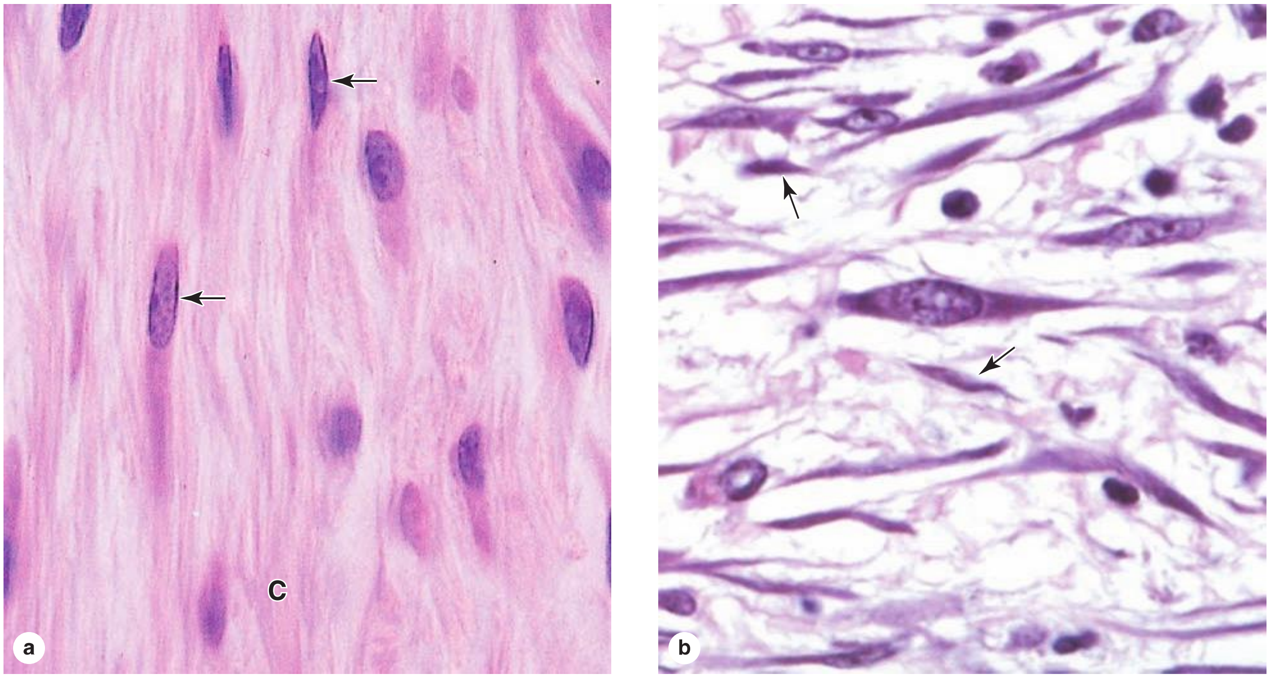
Platelets are cell fragments 2-4 μm in diameter derived from megakaryocytes of bone marrow. Their primary function is to rapidly release the content of their granules upon contact with collagen (or other materials outside of the endothelium) to begin the process of clot formation and reduce blood loss from the vasculature.

(a) In a blood smear, platelets (arrows) are often found as aggregates. Individually they show a lightly stained **hyalomere** region surrounding a more darkly stained central **granulomere** containing membrane-enclosed granules. X1500. Wright.

(b) Ultrastructurally a platelet shows a system of microtubules and actin filaments near the periphery, called the **marginal bundle (MB)**, which is formed as the platelet pinches off from megakaryocyte (Chapter 13), and helps maintain its shape. An open canalicular system (**OCS**) of invaginating membrane vesicles continuous with the plasmalemma facilitates rapid degranulation upon activation and Ca^{2+} release. The central granulomere region contains small dense delta granules (**δG**), larger and more numerous alpha granules (**αG**), and glycogen (**G**). X40,000.

(*Figure 12-13b, with permission, from Dr M. J. G. Harrison, Middlesex Hospital and University College London, UK.*)

FIGURE 5–3 Fibroblasts.

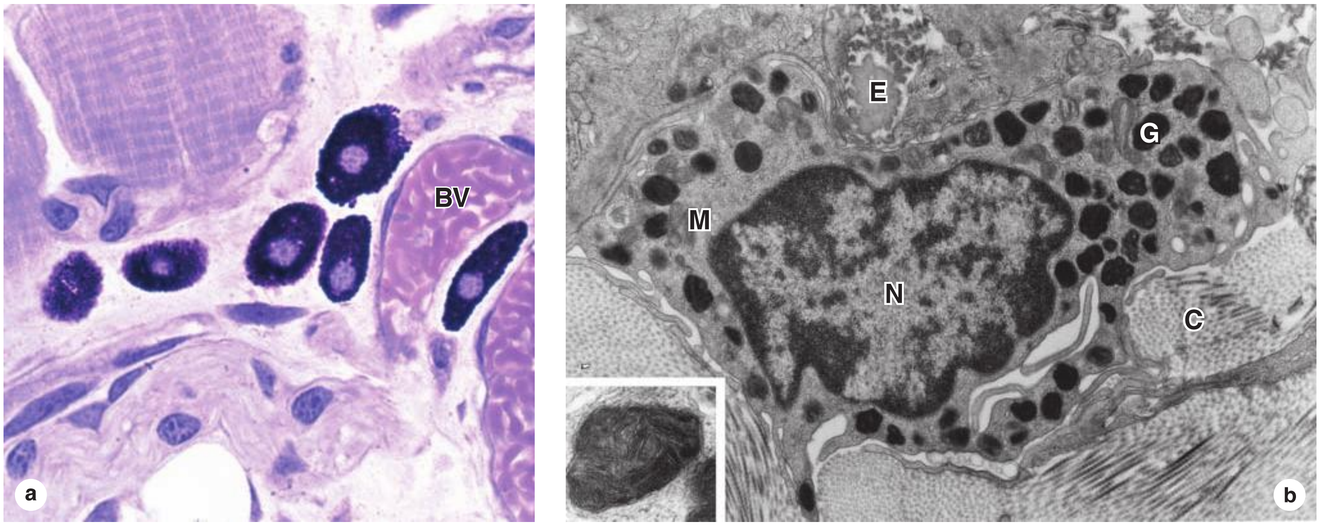


(a) Fibroblasts typically have large active nuclei and eosinophilic cytoplasm that tapers off in both directions along the axis of the nucleus, a morphology often referred to as "spindle-shaped." Nuclei (**arrows**) are clearly seen, but the eosinophilic cytoplasmic processes resemble the collagen bundles (**C**) that fill the ECM and are difficult to distinguish in H&E-stained sections.

(b) Both active and quiescent fibroblasts may sometimes be distinguished, as in this section of dermis. Active fibroblasts have large, euchromatic nuclei and basophilic cytoplasm, while inactive fibroblasts (or fibrocytes) are smaller with more heterochromatic nuclei (**arrows**). The round, very basophilic round cells are in leukocytes. Both X400. H&E.

lecture 5

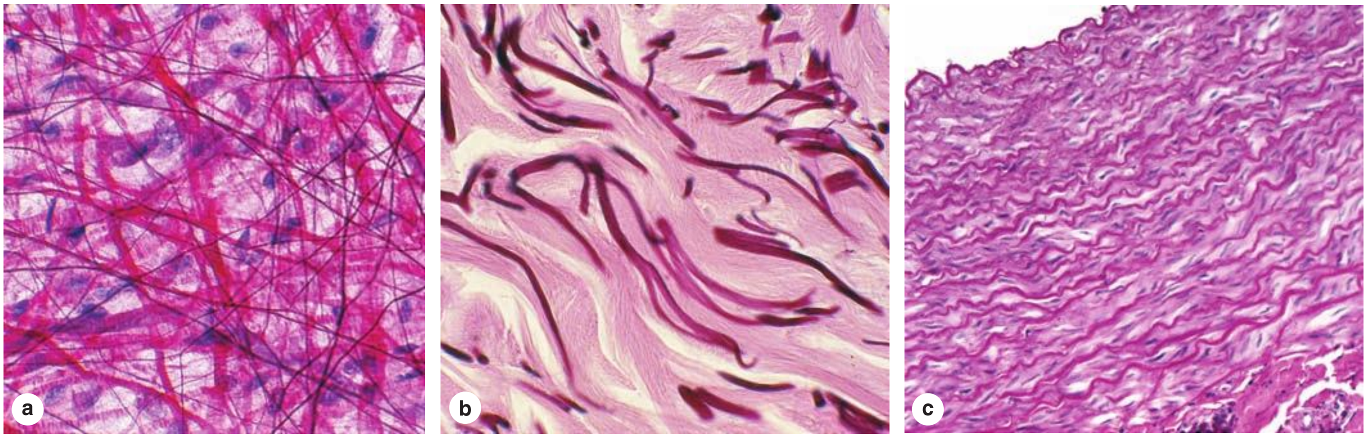
FIGURE 5–5 Mast cells.



Mast cells are components of loose connective tissues, often located near small blood vessels (**BV**). **(a)** They are typically oval shaped, with cytoplasm filled with strongly basophilic granules. X400. PT.

(b) Ultrastructurally mast cells show little else around the nucleus (**N**) besides these cytoplasmic granules (**G**), except for occasional mitochondria (**M**). The granule staining in the TEM is heterogeneous and variable in mast cells from different tissues; at higher magnifications some granules may show a characteristic scroll-like substructure (inset) that contains preformed mediators such as histamine and proteoglycans. The ECM near this mast cell includes elastic fibers (**E**) and bundles of collagen fibers (**C**).

FIGURE 5–13 Elastic fibers.



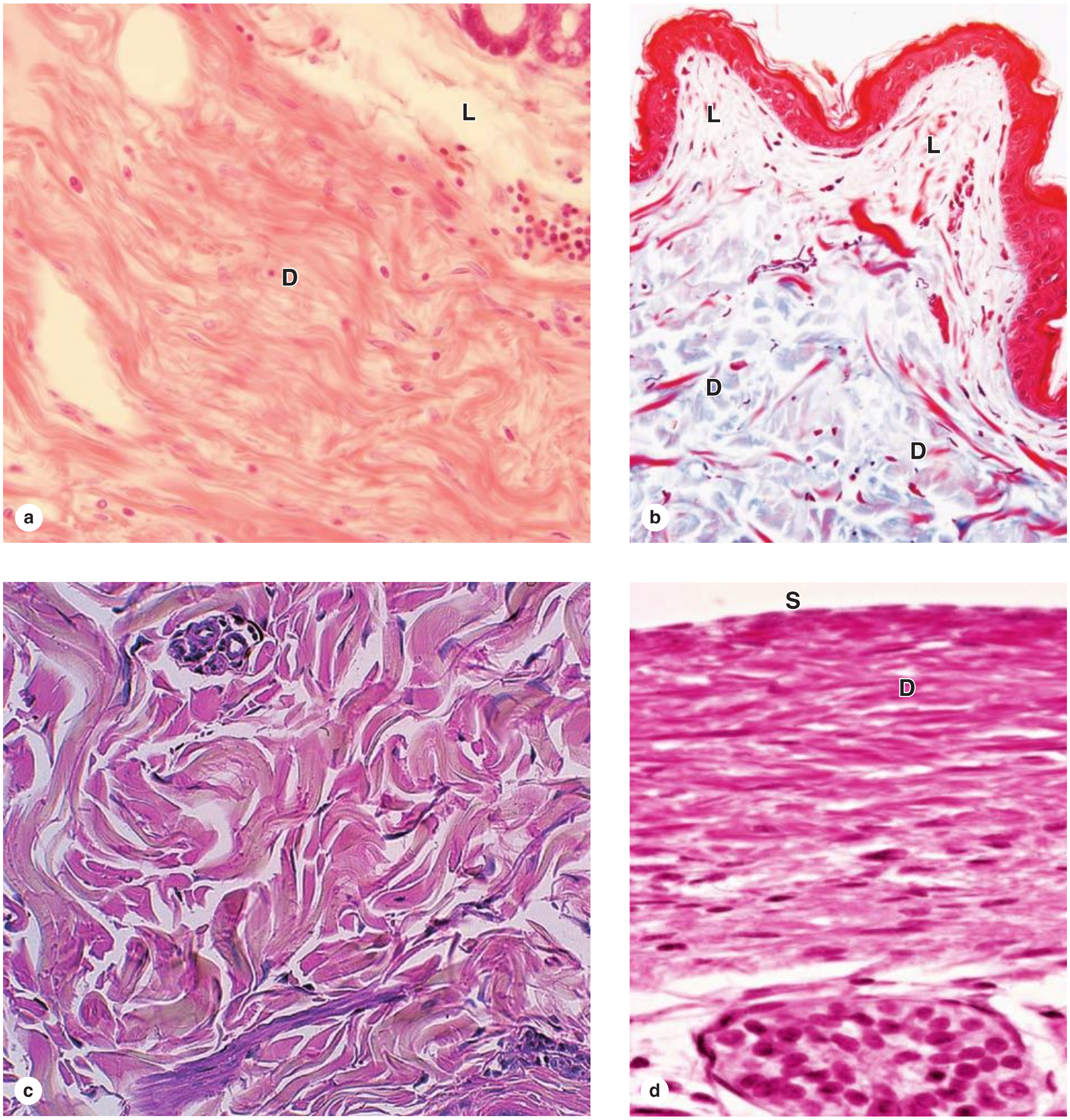
Elastic fibers or lamellae (sheets) add resiliency to connective tissue. Such fibers may be difficult to discern in H&E-stained tissue, but elastin has a distinct, darker-staining appearance with other staining procedures.

(a) The length, diameter, distribution, and density of dark **elastic fibers** are easily seen in this spread preparation of nonstretched connective tissue in a mesentery. X200. Hematoxylin and orcein.

(b) In sectioned tissue at higher magnification, **elastic fibers** can be seen among the acidophilic collagen bundles of dermis. X400. Aldehyde fuchsin.

(c) Elastic lamellae in the wall of the aorta are more darkly stained, incomplete sheets of elastin between the layers of eosinophilic smooth muscle. X80. H&E.

FIGURE 5–21 Loose connective tissue and dense irregular connective tissue.



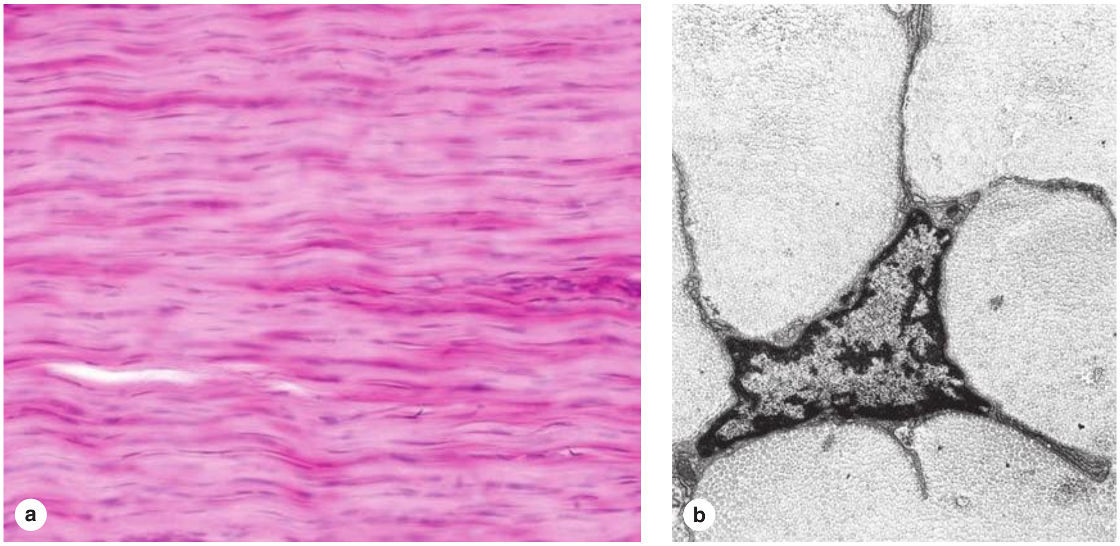
Examples of these connective tissue types shown here indicate the close association that often occurs between these two types. **(a)** Loose connective tissue (**L**) of a gland contains faintly stained ground substance with fine fibers of collagen and frequently forms a thin layer near epithelia, while dense irregular connective tissue (**D**) forms a thicker layer and is invariably much richer in larger bundles of collagen. Scattered leukocytes can be seen in both connective tissues, along with the large irregular spaces of lymphatic vessels (left). X100. H&E.

(b) Trichrome staining of a section from skin demonstrates the blue staining of collagen with this method and its relative density in loose (**L**) and dense irregular (**D**) connective tissue. X100. Mallory trichrome.

(c) Another example of dense irregular connective tissue, showing the randomly arranged large collagen bundles. The arrangement of collagen strengthens the tissues and resists tearing from all directions. X150. H&E.

(d) Dense irregular connective tissue (**D**) forms a thick, protective capsule around many organs such as the testis shown here. Here the capsule is covered by a simple epithelium of serous mesothelial cells (**S**), which produce a hyaluronate-rich lubricant around such organs. X150. H&E.

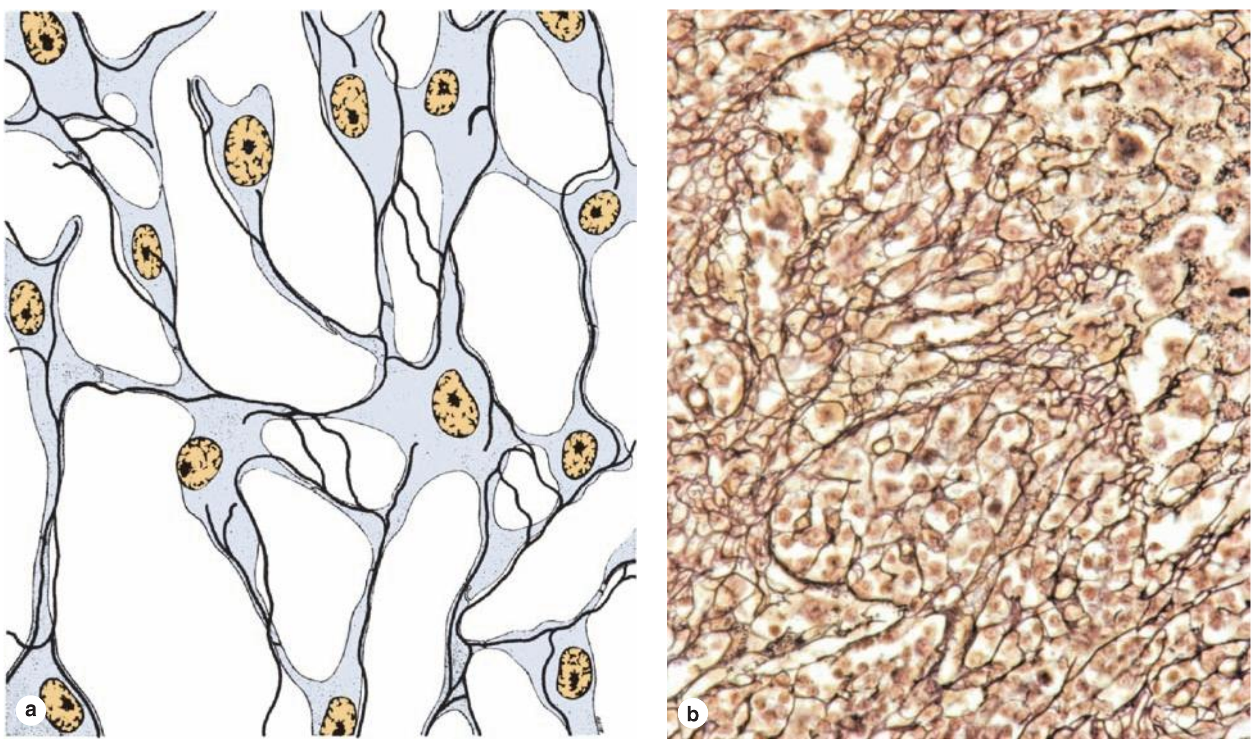
FIGURE **5–22** **Dense regular connective tissue.**



(a) Micrograph shows a longitudinal section of dense regular connective tissue in a tendon. Long, parallel bundles of collagen fibers fill the spaces between the elongated nuclei of fibrocytes. X100. H&E stain.

(b) The electron micrograph shows one fibrocyte in a cross section of tendon, revealing that the sparse cytoplasm of the fibrocytes is divided into numerous thin cytoplasmic processes extending among adjacent collagen fibers. X25,000.

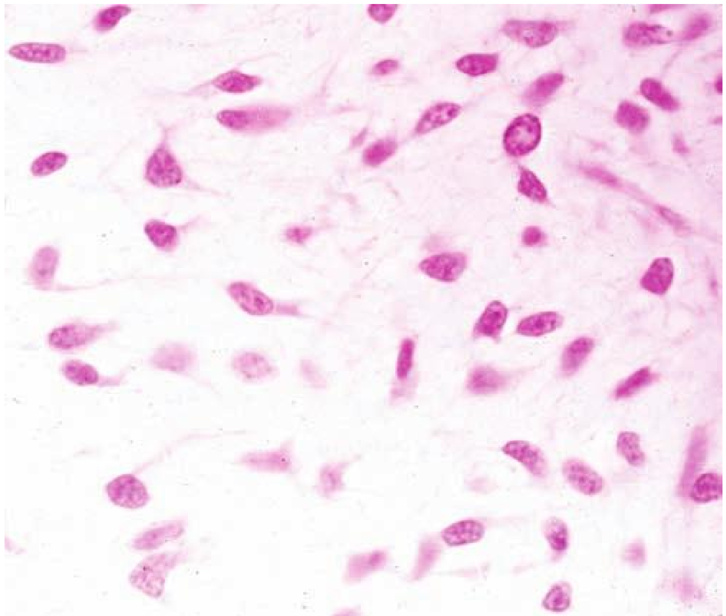
FIGURE **5–23** **Reticular tissue.**



(a) The diagram shows only the fibers and attached reticular cells (free, transient cells are not represented). Reticular fibers of type III collagen are produced and enveloped by the reticular cells, forming an elaborate network through which interstitial fluid or lymph and wandering cells from blood pass continuously.

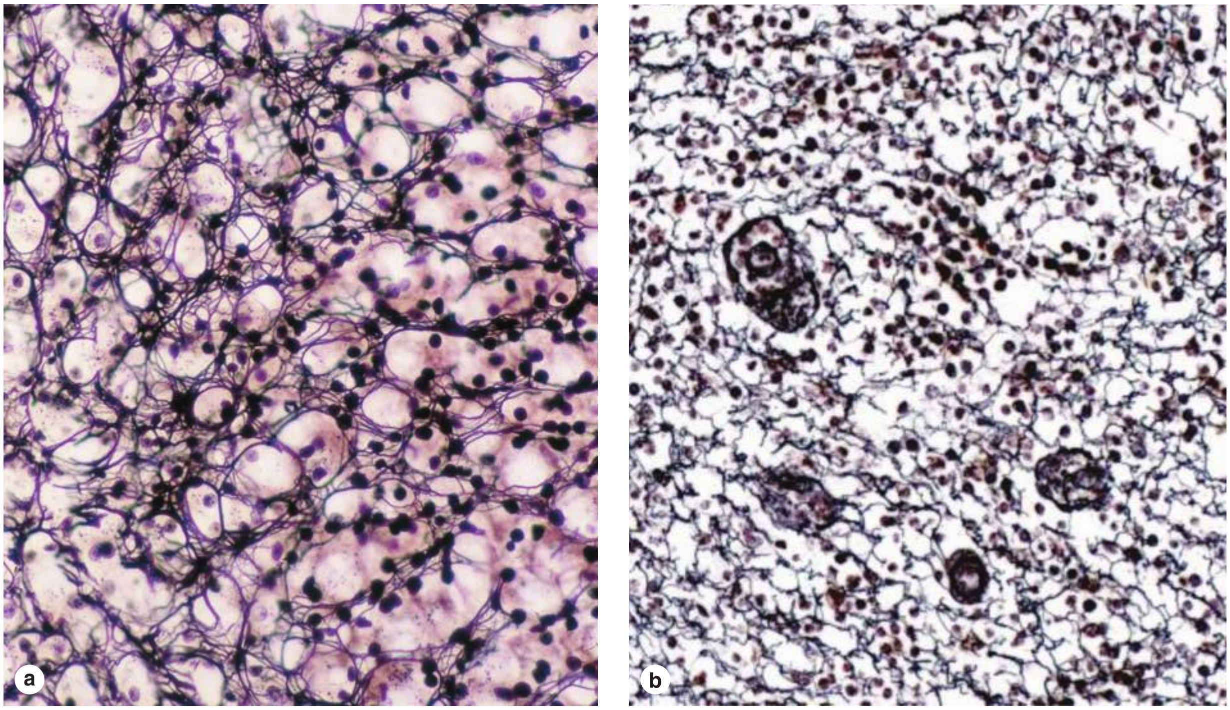
(b) The micrograph shows a silver-stained section of lymph node in which reticular fibers are seen as irregular black lines. Reticular cells are also heavily stained and dark. Most of the smaller, more lightly stained cells are lymphocytes passing through the lymph node. X200. Silver.

FIGURE **5–1** **Embryonic mesenchyme.**



Mesenchyme consists of a population of undifferentiated cells, generally elongated but with many shapes, having large euchromatic nuclei and prominent nucleoli that indicate high levels of synthetic activity. These cells are called **mesenchymal cells**. Mesenchymal cells are surrounded by an ECM that they produced and that consists largely of a simple ground substance rich in hyaluronan (hyaluronic acid), but with very little collagen. X200. Mallory trichrome.

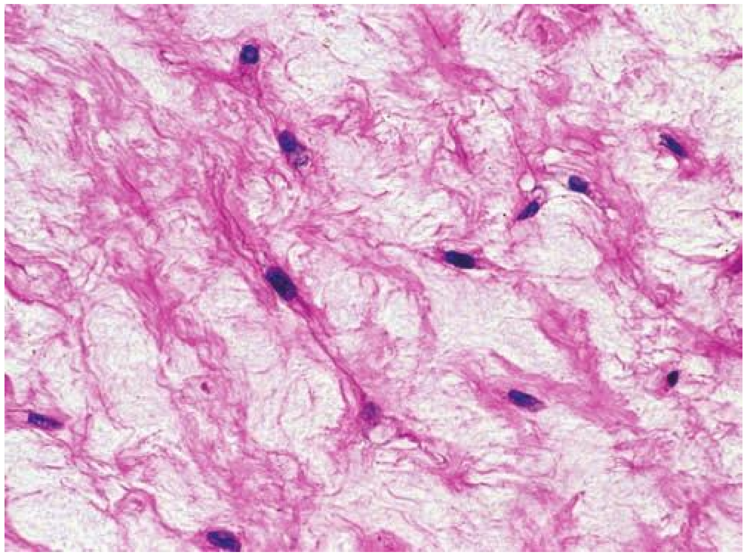
FIGURE **5–12** **Reticular fibers.**



In these silver-stained sections of adrenal cortex **(a)** and lymph node **(b)**, networks of delicate, black **reticular fibers** are prominent. These fibers serve as a supportive stroma in most lymphoid and hematopoietic organs and many endocrine glands. The fibers consist of type III collagen that is heavily glycosylated, producing the black argyrophilia. Cell nuclei are also dark, but cytoplasm is unstained. X100.

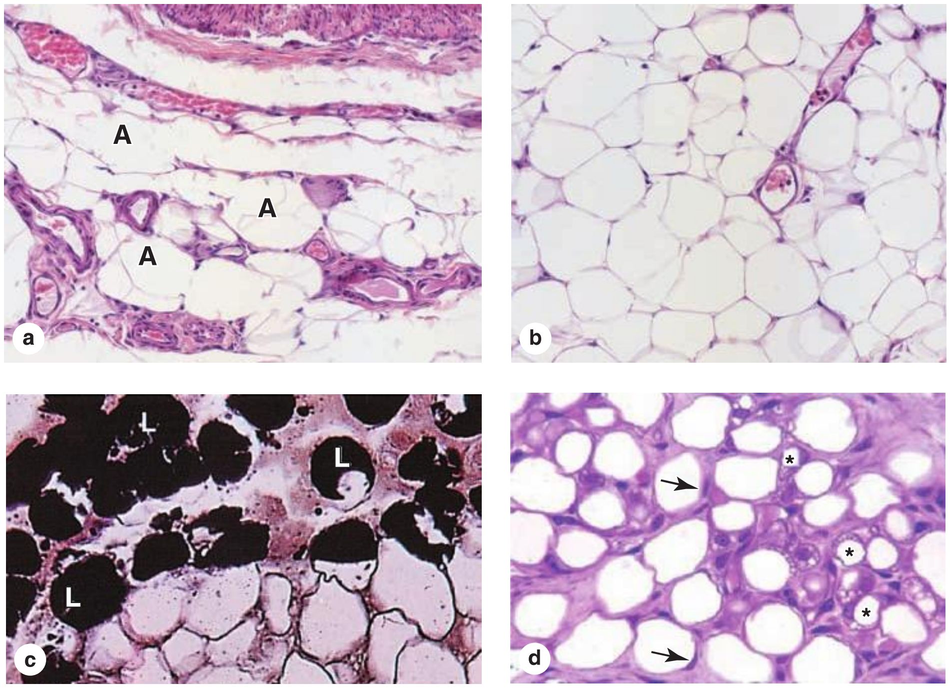
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FIGURE 5–24 Mucoid tissue.



A section of umbilical cord shows large fibroblasts surrounded by a large amount of very loose ECM containing mainly ground substances very rich in hyaluronan, with wisps of collagen. Histologically mucoid (or mucous) connective tissue resembles embryonic mesenchyme in many respects and is rarely found in adult organs. X200. H&E

FIGURE 6–1 **White adipose tissue.**



White or unilocular adipose tissue is commonly seen in sections of many human organs. **(a)** Large white adipocytes (**A**) are seen in the connective tissue associated with small blood vessels. The fat cells are empty because lipid was dissolved away in slide preparation. Nuclei at the cell membranes are visible in some of the fat cells. X100. H&E.

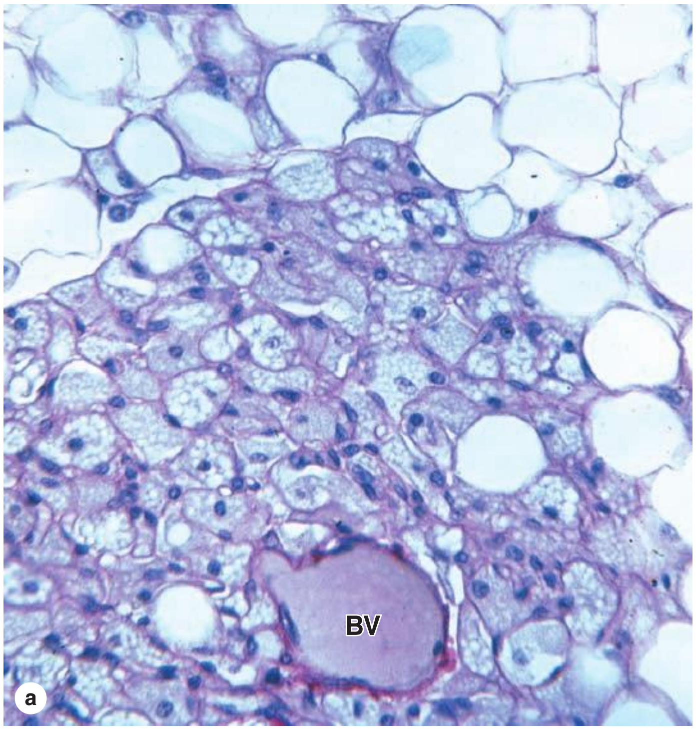
(b) Large (empty) adipocytes predominate in this typical white adipose tissue, which shows only a small portion of microvasculature. In a single histologic section, nuclei of most very large adipocytes are not included. X100. H&E.

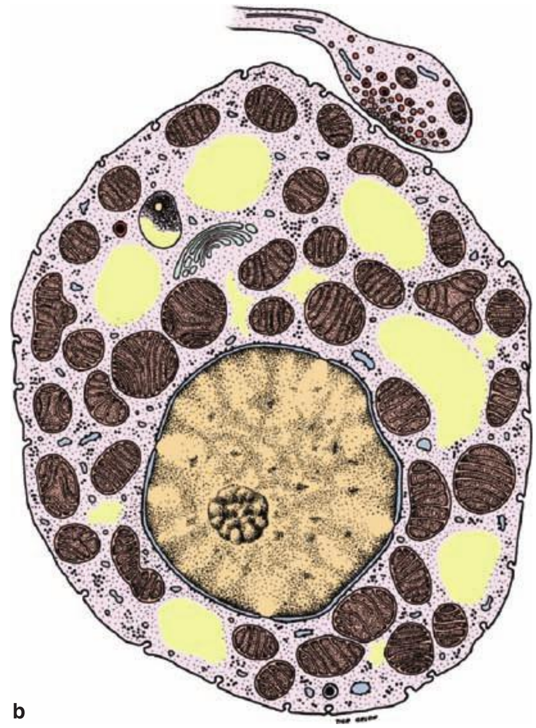
(c) Tissue was fixed here with osmium tetroxide, which preserves lipid (**L**) and stains it black. Many adipocytes in this slide retain at least part of their large lipid droplets. X440. Osmium tetroxide.

(d) The specimen here was from a young mammal, and the adipocytes marked with asterisks are not yet unilocular, having many small lipid droplets in their cytoplasm, which indicates that their differentiation is not yet complete. The eccentric nuclei of unilocular cells are indicated by arrowheads. X200. PT.

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FIGURE **6–4** **Brown adipose tissue.**



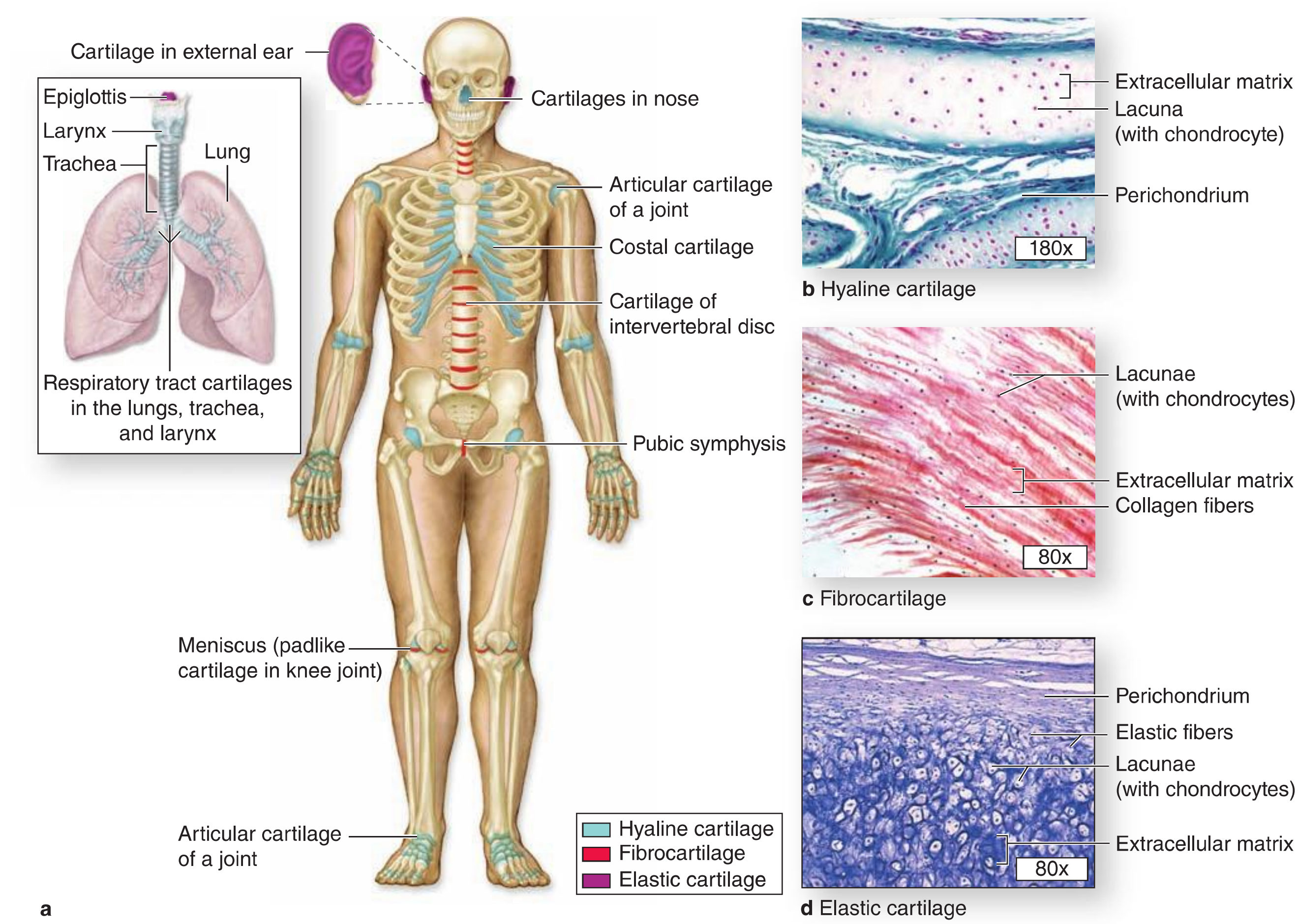


(a) Brown adipose tissue is shown here around a small blood vessel (**BV**) and adjacent white adipose tissue at the top of the photo. Brown adipocytes are slightly smaller and characteristically contain many small lipid droplets and central spherical nuclei. If the lipid has been dissolved from the cells, as shown here, the many mitochondria among the lipid spaces are retained and can be easily discerned. X200. PT.

(b) A diagram of a single multilocular adipocyte showing the central nucleus, numerous small lipid droplets (yellow), and many mitochondria. Also shown is a sympathetic nerve ending that releases norepinephrine to stimulate mitochondrial production of heat.

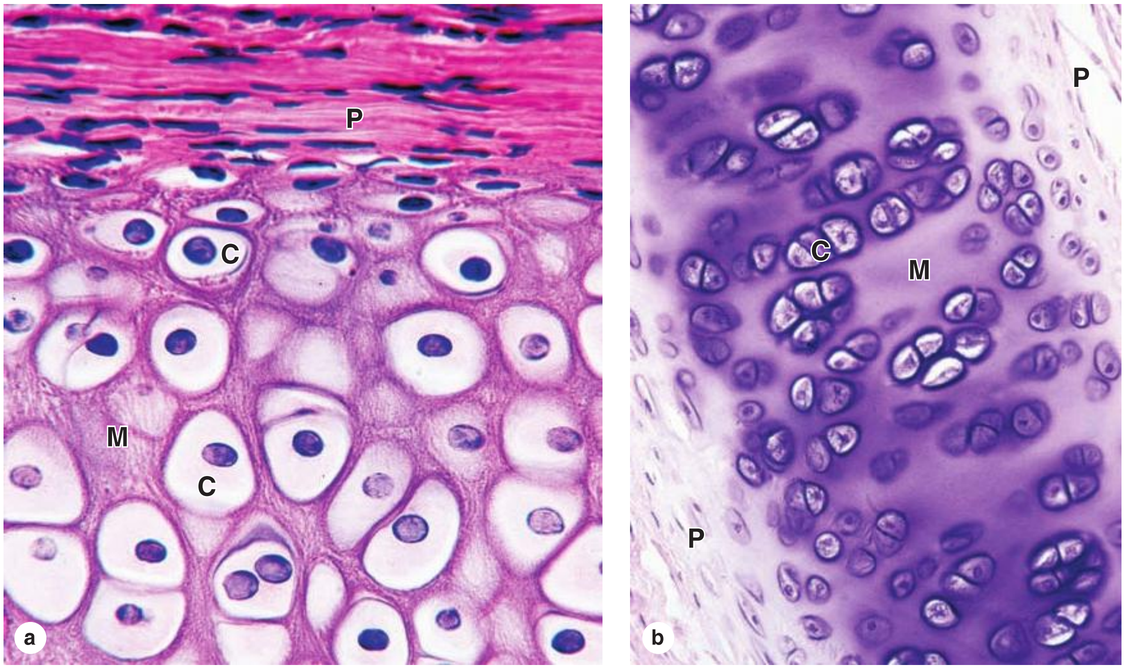
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FIGURE 7–1 Distribution of cartilage in adults.



(a) There are three types of adult cartilage distributed in many areas of the skeleton, particularly in joints and where pliable support is useful, as in the ribs, ears, and nose. Cartilage support of other tissues throughout the respiratory tract is also prominent. The photomicrographs show the main features of **(b)** hyaline cartilage, **(c)** fibrocartilage, and **(d)** elastic cartilage. Dense connective tissue of perichondrium is shown here with hyaline and elastic cartilage.

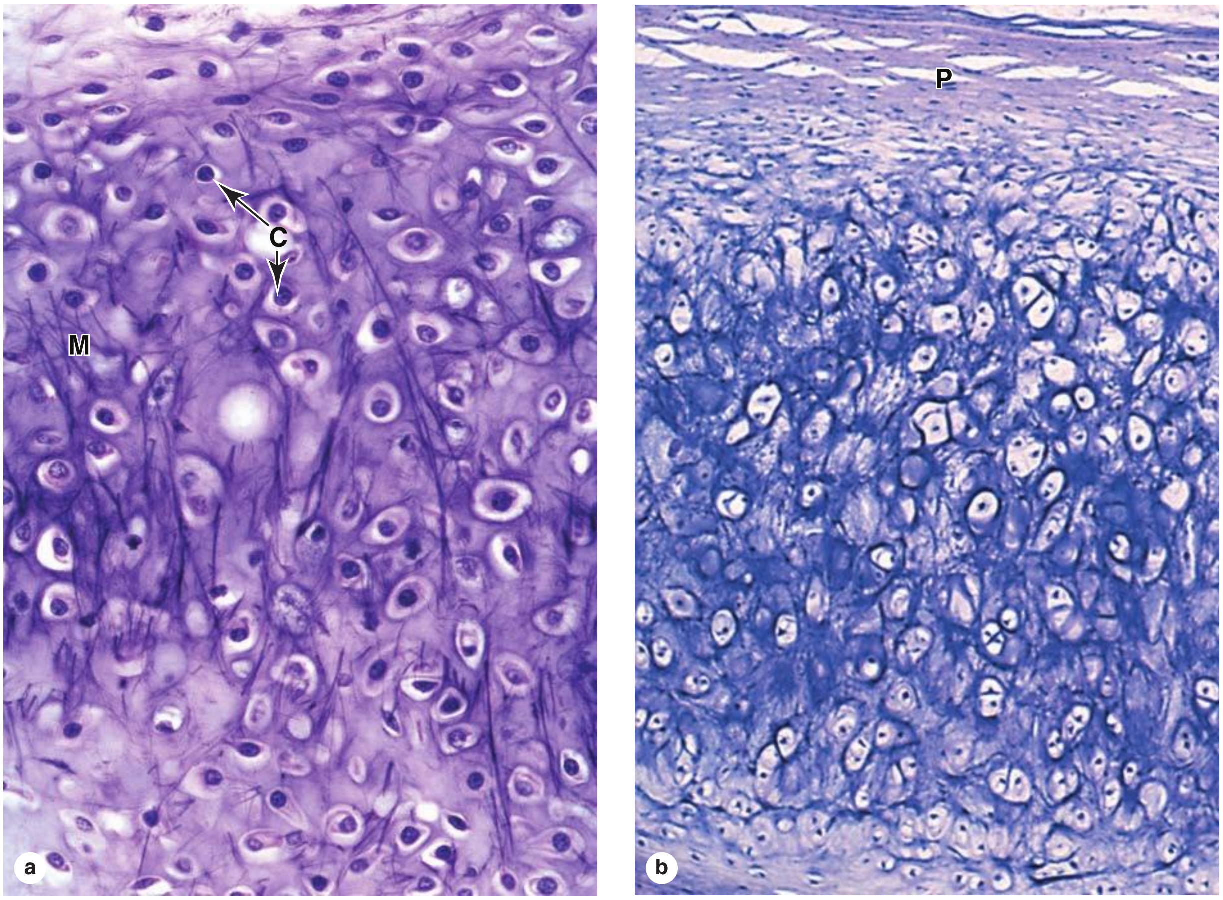
FIGURE **7–3** **Hyaline cartilage.**



(a) The upper part of the photo shows the more acidophilic perichondrium (**P**), an example of dense connective tissue consisting largely of type I collagen. There is a gradual transition and differentiation of cells from the perichondrium to the cartilage, with elongated fibroblastic cells becoming larger and more rounded chondroblasts and chondrocytes (**C**) located within spaces or lacunae surrounded by the matrix (**M**) secreted by the cells. X200. H&E.

(b) The thin region of hyaline cartilage shown here has perichondrium (**P**) on both sides and shows larger lacunae containing isogenous groups of chondrocytes (**C**) within the matrix (**M**). Such groups of two, four, or more cells are produced by mitosis; the cells will separate into individual lacunae as they begin to secrete matrix. X160. H&E.

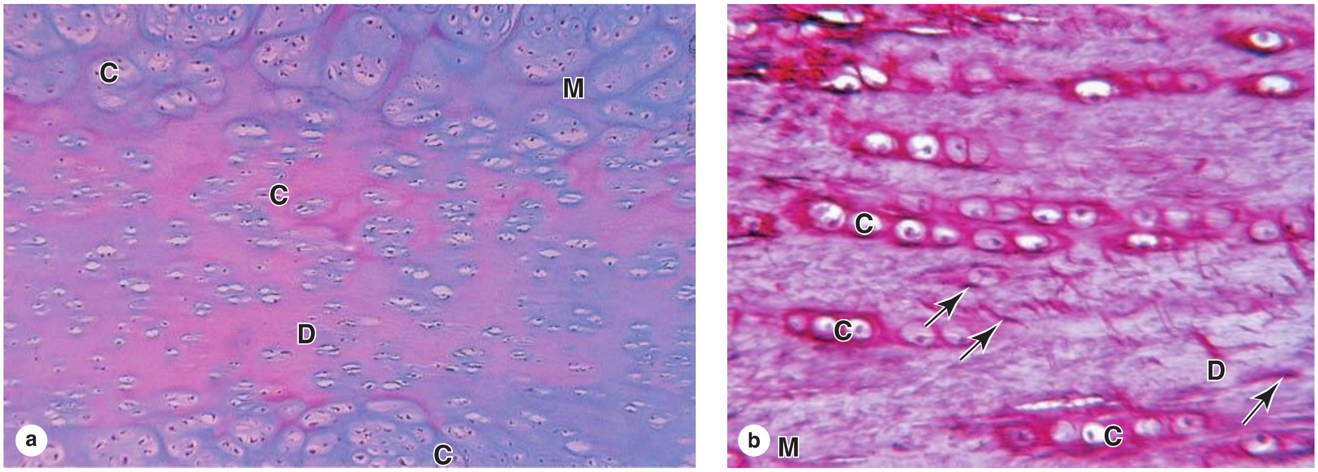
FIGURE **7–4** **Elastic cartilage.**



The chondrocytes (**C**) and overall organization of elastic cartilage are similar to those of hyaline cartilage. Stains for elastin, however, reveal many dark-staining elastic fibers in the matrix (**M**), in addition to the major components found in hyaline matrix. Elastic fibers provide greater flexibility to this form of cartilage. The section in part **b** includes perichondrium (**P**) that is also similar to that of hyaline cartilage. **(a)** X160. Hematoxylin and orcein. **(b)** X100. Weigert resorcin-fuchsin.

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FIGURE 7–5 **Fibrocartilage.**

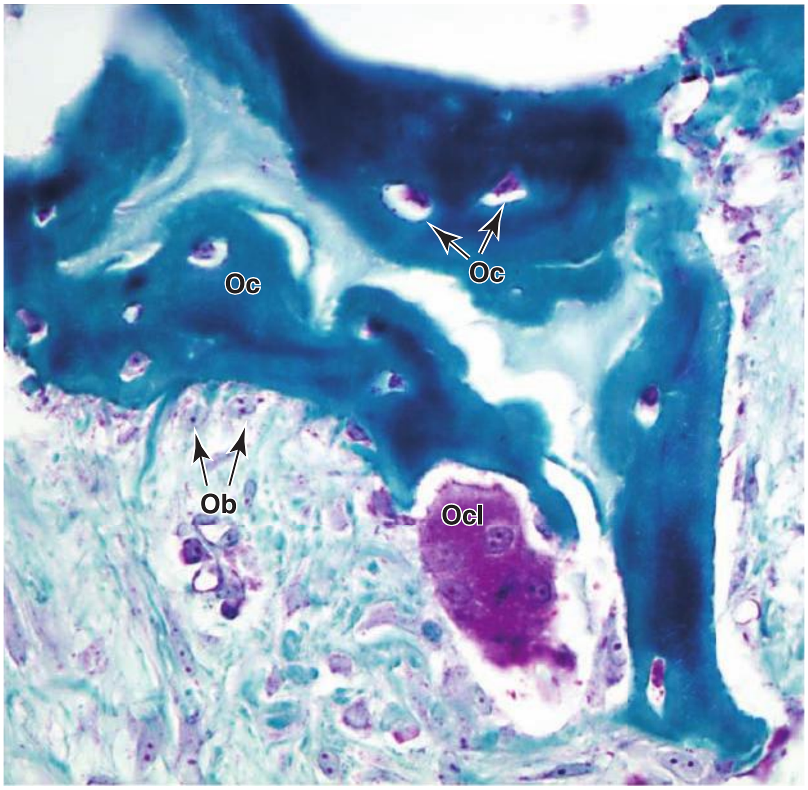


Fibrocartilage varies in different organs, but is essentially a mixture of hyaline cartilage and dense connective tissue.

(a) A section of pubic symphysis shows lacunae with isolated and grouped chondrocytes (**C**) surrounded by matrix (**M**) and separated in some areas by dense regions (**D**) containing more concentrated acidophilic type I collagen. No separate perichondrium is present on fibrocartilage. X100. H&E.

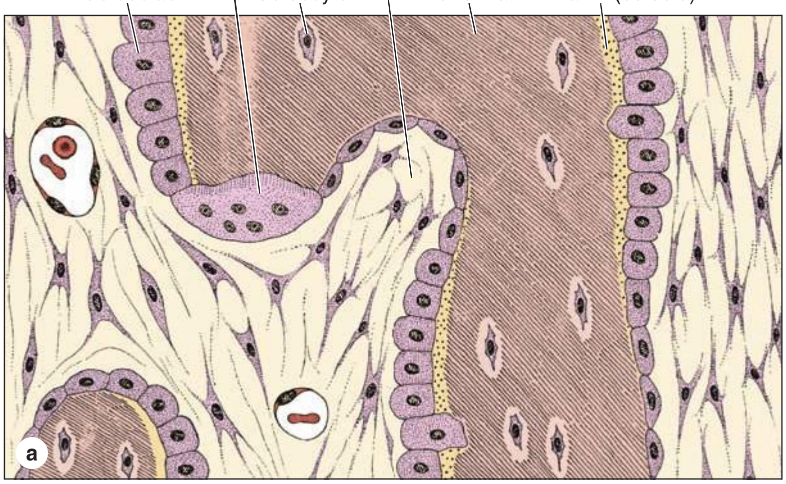
(b) At higher magnification in a small region of intervertebral disc, the axially arranged aggregates of chondrocytes (**C**) are seen to be surrounded by small amounts of matrix and separated by larger regions with dense collagen (**D**) and a small number of fibroblasts with elongated nuclei (arrows). X250. Picrosirius-hematoxylin.

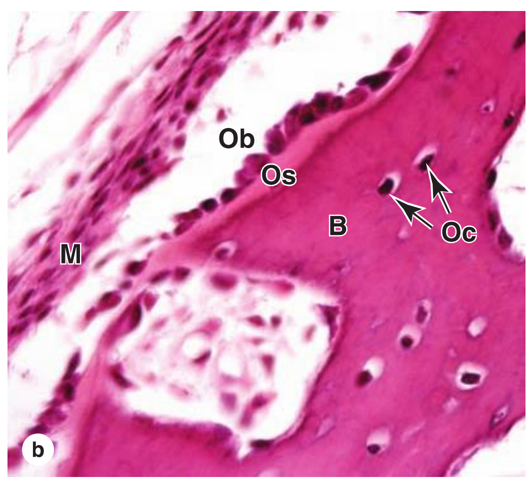
FIGURE 8–2 Osteoblasts, osteocytes, and an osteoclast.



Bone-forming osteoblasts (**Ob**) differentiate from osteoprogenitor cells in the periosteum and endosteum, and cover the surfaces of existing bone matrix. Osteoblasts secrete **osteoid** containing collagen type I, proteoglycans and other molecules, and matrix vesicles. As osteoid undergoes calcification, hardens, and traps the osteoblasts, these cells differentiate further as osteocytes (**Oc**), which occupy lacunae surrounded by bony matrix. The much less numerous large, multinuclear osteoclasts (**Ocl**), produced by the fusion of blood monocytes, reside on bony surfaces and erode the matrix during bone remodeling. 400X. Mallory trichrome.

FIGURE 8–3 Osteoblasts and osteocytes.



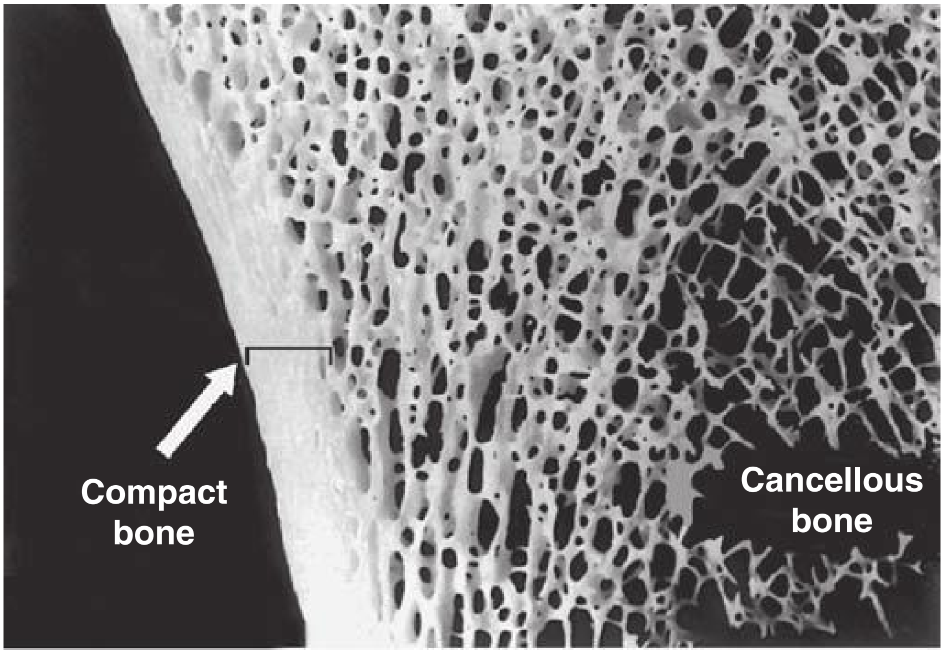


(a) Diagram showing the relationship of osteoblasts to osteoid, bone matrix, and osteocytes. Osteoblasts and most of the larger osteoclasts are part of the endosteum covering the bony trabeculae.

(b) The photomicrograph of developing bone shows the location and morphologic differences between active osteoblasts (**Ob**) and osteocytes (**Oc**). Rounded osteoblasts, derived from cells in the adjacent mesenchyme (**M**), appear as a layer of cells adjacent to a very thin layer of lightly stained osteoid (**Os**) that covers the more heavily stained bony matrix (**B**). Inactive osteoblasts are more flattened and cover the bony surface shown near the top here. Osteocytes are located within lacunae surrounded by matrix. X300. H&E.

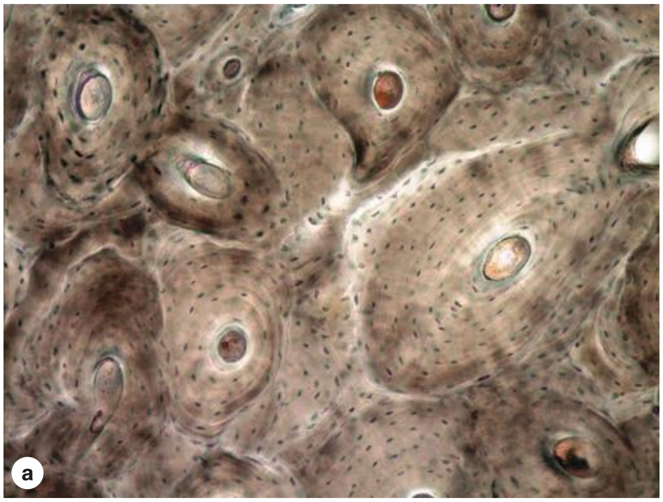
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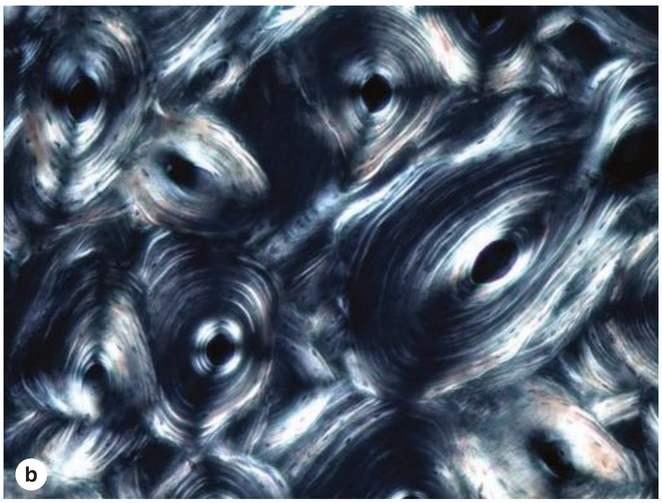
FIGURE 8–7 **Compact and cancellous bone.**



Macroscopic photo of a thick section of bone showing the cortical **compact bone** and the lattice of trabeculae in **cancellous bone** at the bone's interior. In living tissue the compact bone is covered externally with periosteum and all trabecular surfaces of cancellous bone are covered with endosteum. X10.

FIGURE 8–8 Lamellar bone.

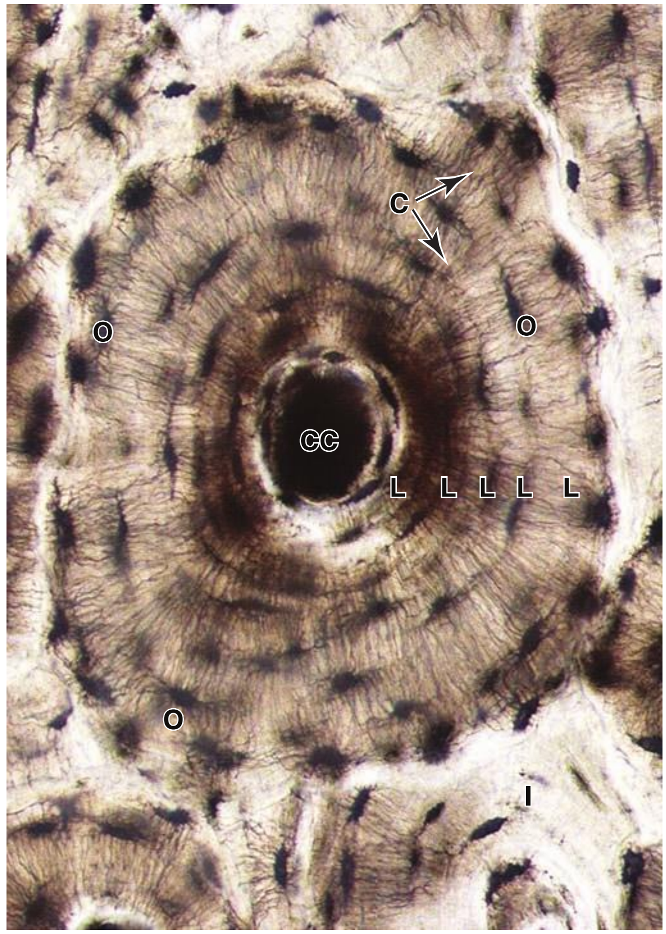




Two photographs of the same area of an unstained section of compact bone, showing osteons with concentric lamellae around central canals. Lamellae are seen only faintly by bright-field microscopy **(a)**, but they appear as alternating bright and dark bands under the polarizing light microscope **(b)**. Bright bands are due to birefringence from the highly ordered collagen fibers in a lamella. Alternating bright and dark bands indicate that fibers in successive lamellae have different orientations, an organization that makes lamellar bone very strong. Both X100.

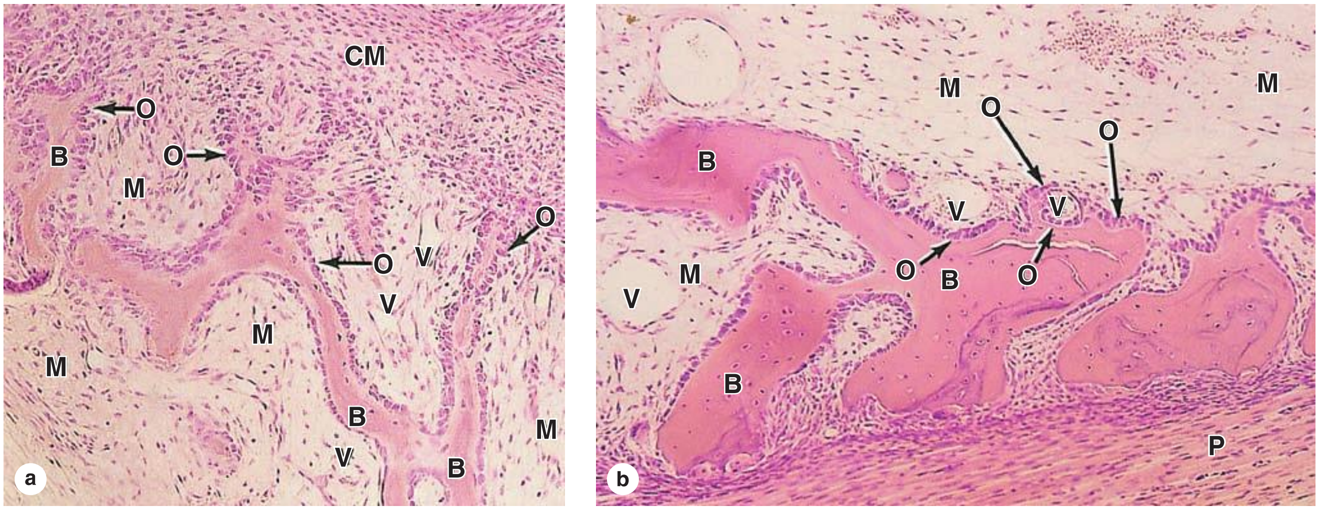
(*With permission, from Dr Matt Allen, Indiana University School of Medicine, Indianapolis.*)

FIGURE 8–9 An osteon.



Osteons (Haversian systems) constitute most of the compact bone. Shown here is an osteon with four to five concentric lamellae (**L**) surrounding the central canal (**CC**). Osteocytes (**O**) in lacunae are in communication with each other and with the central canal and periphery of the osteon via through hundreds of dendritic processes located within fine canaliculi (**C**). Also shown are the partial, interstitial lamellae (**I**) of an osteon partially eroded when the intact osteon was formed. Ground bone. X500.

FIGURE 8–13 Intramembranous ossification.

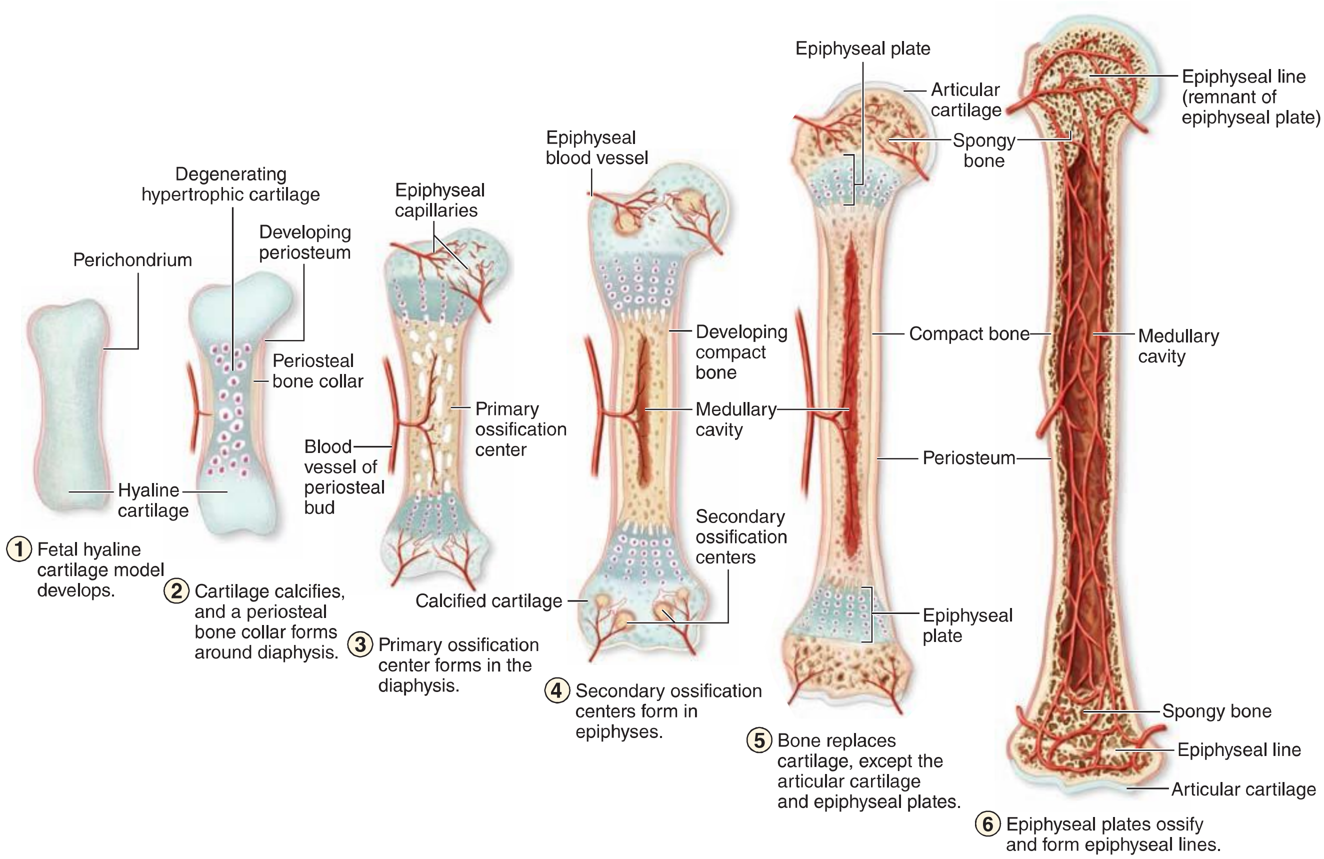


A section of fetal pig mandible developing by intramembranous ossification. **(a)** Areas of typical mesenchyme (**M**) and condensed mesenchyme (**CM**) are adjacent to layers of new osteoblasts (**O**). Some osteoblasts have secreted matrices of bone (**B**), the surfaces of which remain covered by osteoblasts. Between these trabeculae of new woven bone are areas with small blood vessels (**V**). X40. H&E.

(b) At higher magnification another section shows these same structures, along with the developing periosteum (**P**) adjacent to masses of woven bone that will soon merge to form a continuous plate of bone. The larger mesenchyme-filled region at the top is part of the developing marrow cavity. Osteocytes in lacunae can be seen within the eosinophilic bony matrix. X100. H&E.

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FIGURE **8–14** **Osteogenesis of long bones by endochondral ossification.**

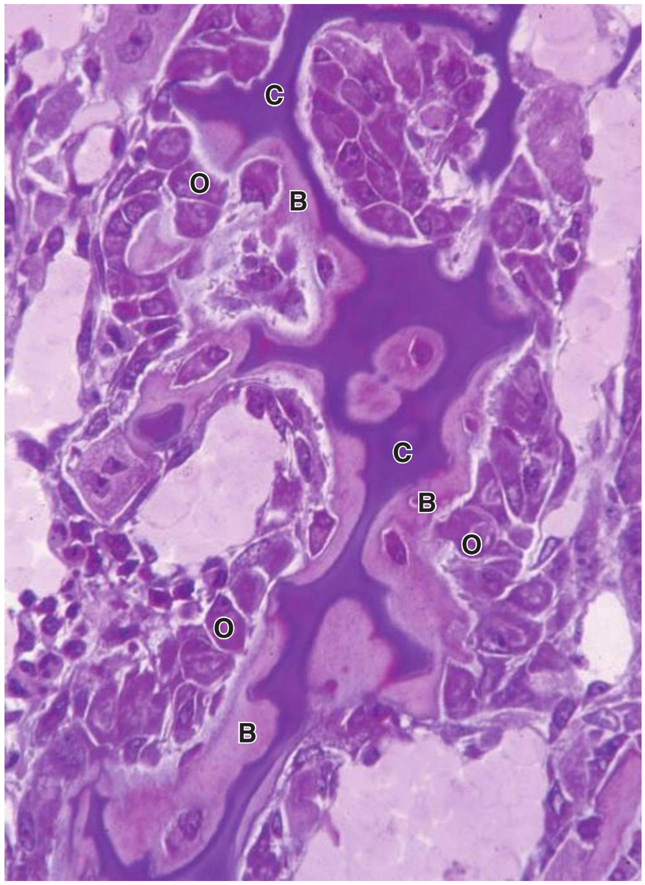


This process, by which most bones form initially, begins with embryonic models of the skeletal elements made of hyaline cartilage (**1**). Late in the first trimester, a bone collar develops beneath the perichondrium around the middle of the long bones' cartilage models, causing degeneration of the underlying cartilage (**2**).

This is followed by invasion of the degenerating cartilage by capillaries and osteoprogenitor cells from what is now the periosteum to produce a **primary ossification center** in the diaphysis (**3**). Here osteoid is deposited by the new osteoblasts, undergoes calcification into woven bone, and is remodeled as compact bone.

(**4**) Around the time of birth **secondary ossification centers** begin to develop by a similar process in the epiphyses. During childhood the primary and secondary ossification centers gradually come to be separated only by the **epiphyseal plate** (**5**) that provides for continued bone elongation. The two ossification centers do not merge until the epiphyseal plate disappears (**6**) when full stature is achieved. Osteoblasts of the periosteum provide for growth in the bone's diameter.

FIGURE 8–15 Cells and matrices of a primary ossification center.



A small region of a primary ossification center showing key features of endochondral ossification. Compressed remnants of calcified cartilage matrix (**C**) are basophilic and devoid of chondrocytes. This material becomes enclosed by more lightly stained osteoid and woven bone (**B**) which contains osteocytes in lacunae. The new bone is produced by active osteoblasts (**O**) arranged as a layer on the remnants of old cartilage. X200. Pararosaniline–toluidine blue.

مع التمنيات بالتوفيق والسداد